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ALL ABOUT SPACE

ISSUE 148
OCTOBER 2023

FASTER THAN THE SPEED OF LIGHT

HAS NEW RESEARCH FINALLY UNCOVERED
A WAY TO CONQUER EINSTEIN'S THEORY
OF SPECIAL RELATIVITY?

SPECIAL REPORT
**WHERE DID LIFE
COME FROM?**



**IMPOSSIBLE
COSMIC
PHENOMENA**

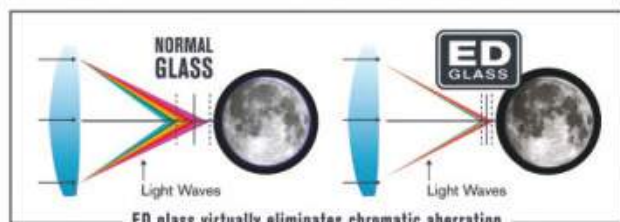
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ISSUE 148



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NEWSLETTER



It's said that nothing can travel faster than the speed of light. Einstein's theory of special relativity states that massless photons travelling within a vacuum are so fast, at speeds of 299,338 kilometres (186,000 miles) per second, that nothing in the universe can exceed them.

Of course, physicists are continually trying to push the boundaries of our knowledge, as you'll discover in our cover feature this issue. Will Einstein's theory continue to stand the test of time?

Elsewhere this issue, we reveal the top stargazing events of 2024 that can't be missed. From solar and lunar eclipses to meteor showers and conjunctions, there's something for everyone to observe, whether you have a telescope, binocular or are just content with using your unaided eye. We also keep you up to date with the latest space news and images from ground and space-based telescopes alongside our regular features: Ask Space, where our experts answer your questions; reviews of the latest astronomy kit, books and software; future tech; interviews and more.

Wishing you clear skies for the month ahead!

GEMMA LAVENDER
Editor

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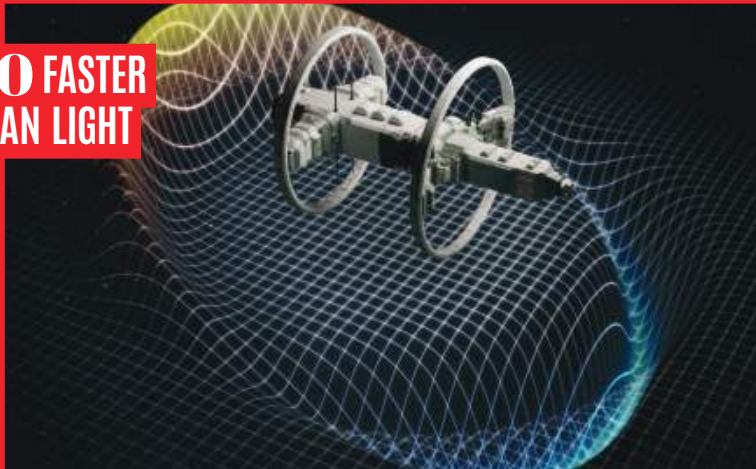
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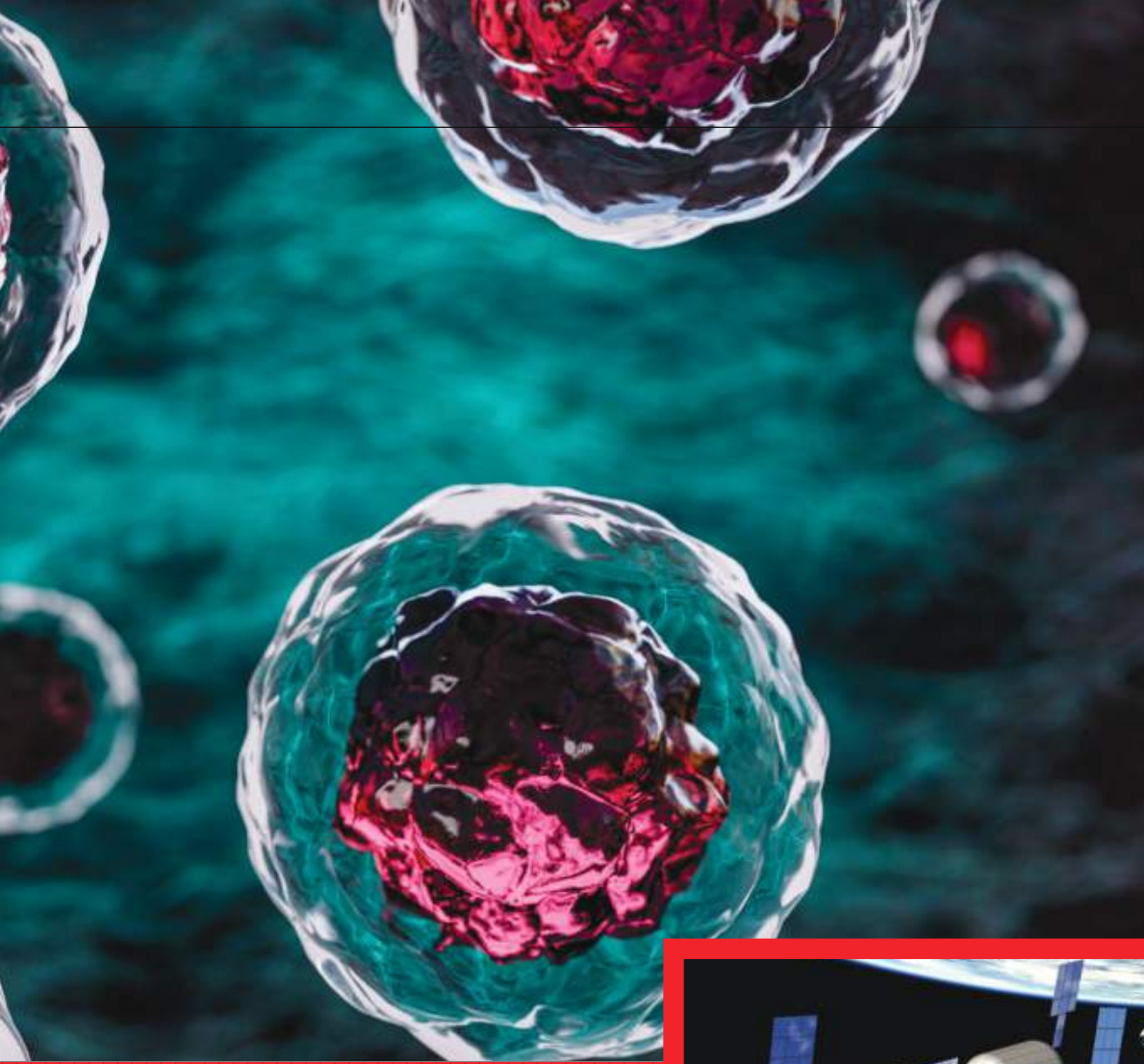
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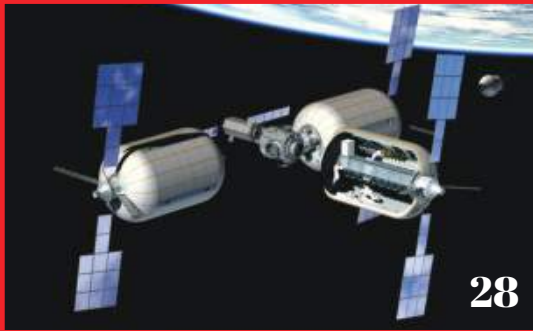


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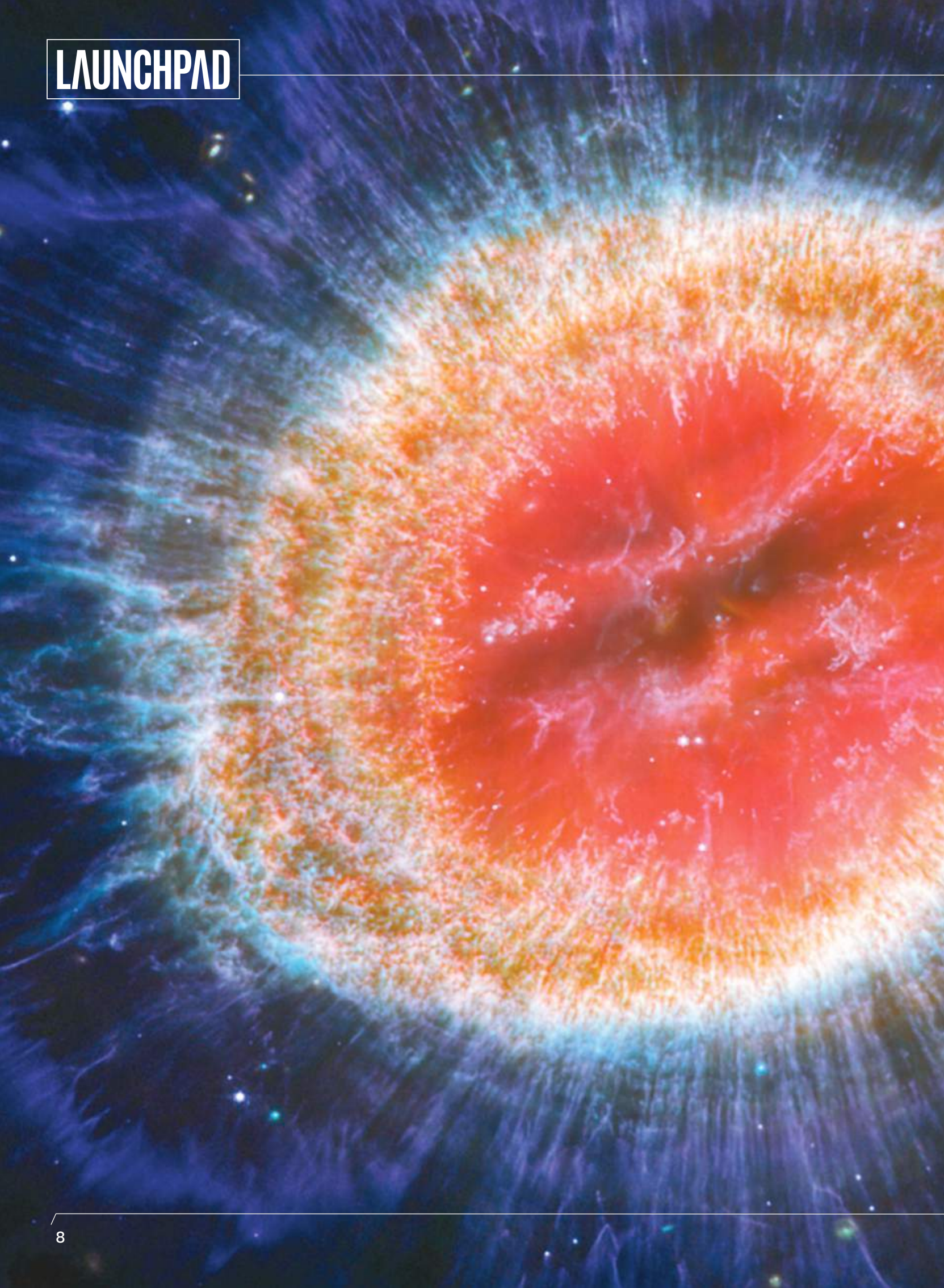
Ghostly glow of a distant galaxy

A distant galaxy sparkles with the soft glow of its many tiny stars in a new photo from the Hubble Space Telescope. The galaxy, named ESO 300-16, is located about 28.7 million light years away from Earth in the constellation of Eridanus and appears as a celestial cloud of sparkling stars against the dark backdrop of space. Other galaxies and stars are also featured in the new Hubble image, providing a captivating view of this cosmic neighbourhood. “The galaxy ESO 300-16 looms over this image,” European Space Agency (ESA) officials said, adding that it “is a ghostly assemblage of stars which resembles a sparkling cloud”.

This recent view of ESO 300-16 was taken using the Advanced Camera for Surveys instrument on Hubble, which is a joint mission led by NASA and the ESA. It’s part of a series aimed at surveying Earth’s galactic neighbours. “Around three-quarters of the known galaxies suspected to lie within 10 megaparsecs [32 million light years] of Earth have been observed by Hubble in enough detail to resolve their brightest stars and establish the distances to these galaxies,” ESA officials said. “A team of astronomers proposed using small gaps in Hubble’s observing schedule to acquaint ourselves with the remaining quarter of the nearby galaxies.”

ESO 300-16 is classified as an irregular galaxy due to its indistinct shape and lack of a central bulge or spiral arms. Instead it resembles the shape of a cloud, composed of many tiny stars all clumped together. The stars give off a soft, diffuse light that surrounds a bubble of bright, blue gas at the galaxy’s core. The brighter foreground objects represent nearby stars and galaxies.

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21 August 2023

A mesmerising look at the Ring Nebula

Approximately 2,200 light years away lies the Cheerio-shaped remains of a dying star – remnants that form a structure famously known as the Ring Nebula. On 21 August, scientists announced the James Webb Space Telescope had struck gold once again with a rather beautiful new view of this iconic cosmic halo. “When we first saw the images, we were stunned by the amount of detail in them. The bright ring that gives the nebula its name is composed of about 20,000 individual clumps of dense molecular hydrogen gas, each of them about as massive as Earth,” Roger Wesson of Cardiff University said.

By capturing infrared light wavelengths emitted by the nebula, Webb unveiled information about the inner ring’s filament structure, as well as approximately ten concentric ‘arcs’ in the outer regions of the phenomenon – features that actually came as a surprise. “These arcs must have formed about every 280 years as the central star was shedding its outer layers,” Wesson said. “When a single star evolves into a planetary nebula, there’s no process that we know of that has that kind of time period. Instead these rings suggest that there must be a companion star in the system, orbiting about as far away from the central star as Pluto does from our Sun. As the dying star was throwing off its atmosphere, the companion star shaped the outflow and sculpted it,” Wesson said, highlighting that “no previous telescope had the sensitivity and the spatial resolution to uncover this subtle effect.”

With Webb, the team was able to notice some “curious spikes” pointing directly away from the central star within the ring. These spikes were apparently only faintly visible in images taken by the Hubble Space Telescope. “We think these could be due to molecules that can form in the shadows of the densest parts of the ring, where they are shielded from the direct intense radiation from the hot central star,” Wesson said. He explained that the team identified a narrow band of emission coming from some molecules within the ring, known as polycyclic aromatic hydrocarbons, or PAHs. PAHs are essentially carbon-bearing molecules, but importantly for these new Webb results, they were not expected to form within the nebula.



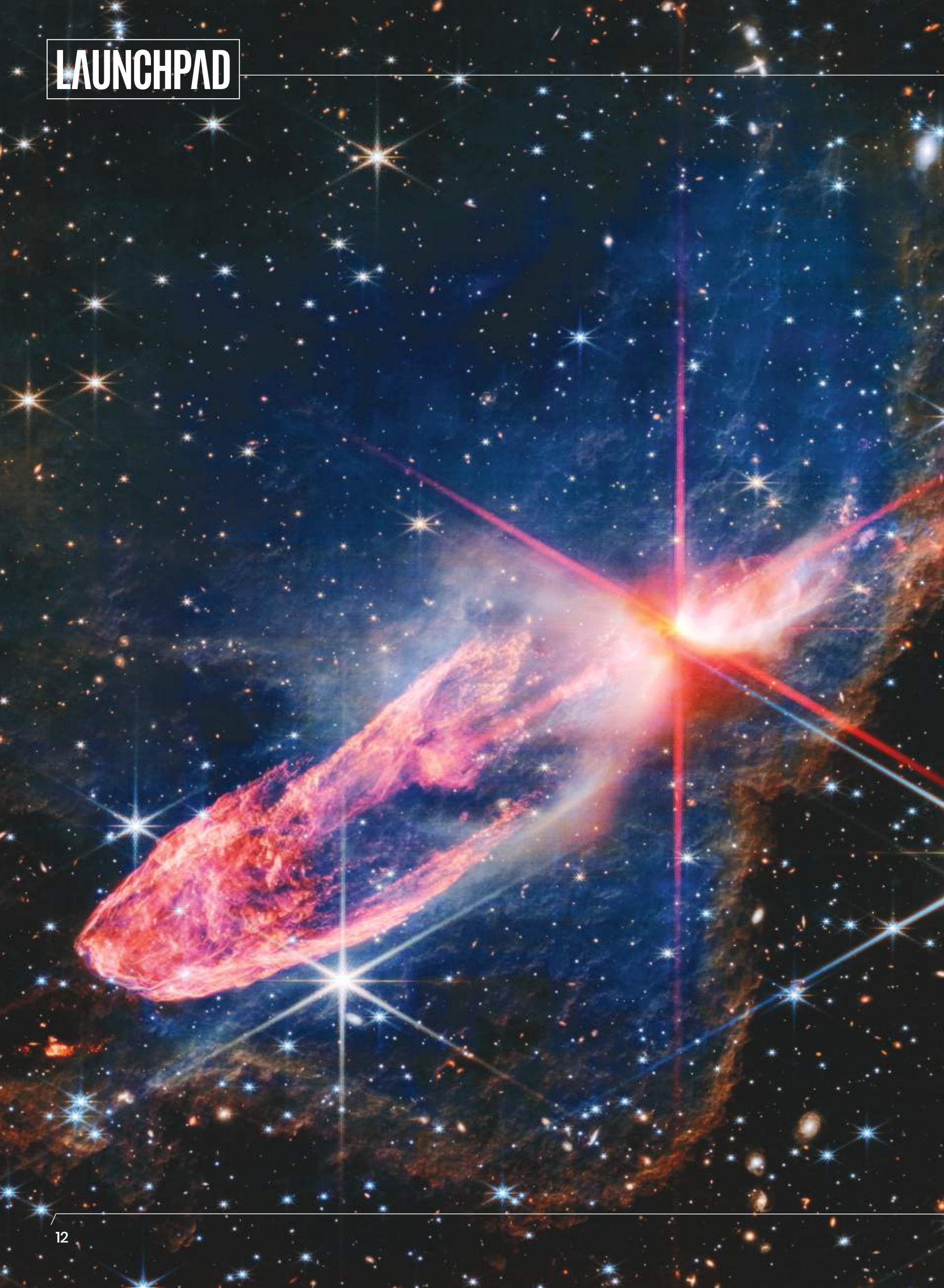
10 August 2023

Dark Energy Camera reveals galaxies in a 'tug of war'

Astronomers have caught a tug of war between a massive galaxy and its smaller dwarf galaxy neighbour. The larger galaxy engaged in this cosmic tussle is the massive barred-spiral galaxy NGC 1532, also known as Haley's Coronet. It's located about 55 million light years away from Earth in the direction of the southern constellation of Eridanus, iconic for its striking resemblance to a river. The much smaller dwarf galaxy is NGC 1531, which falls around 42 million light years away from our Solar System and is being dragged towards its doom. Beyond highlighting the very one-sided cosmic struggle between these galaxies, the image, captured by the Dark Energy Camera (DECam) on the Víctor M. Blanco 4-meter Telescope at Cerro Tololo Inter-American Observatory, could also reveal how galaxies grow by cannibalising smaller companions.

Scientists currently think that large galaxies, such as the Milky Way, grow over the course of billions of years by continuously merging with smaller nearby dwarf galaxies. The new image of Haley's Coronet and NGC 1531 could offer hints as to how the early stages of those merger events play out. The DECam picture shows an edge-on view of the spiral arms in Haley's Coronet, revealing that the further arm is being wrenched upwards as it pulls on the dwarf galaxy. This distorted radial feature demonstrates that while NGC 1531 is being hopelessly overtaken, it still has a noticeable effect on its larger companion.

The image also reveals a bridge made of gas and dust stretching between the two galaxies. It's said to be held in place by tidal forces arising from the gravitational influence of both bodies. Also present, but less obvious in this image, are bouts of star formation within both Haley's Coronet and NGC 1531, triggered by interactions between the realms. But one element of Haley's Coronet appears unconcerned with the ongoing battle with NGC 1531 – the spiral arm closer to Earth looks relaxed as it hangs down from the site of the collision. Throughout the 13.8-billion-year history of the universe, cosmic feeding events such as the one underway between Haley's Coronet and NGC 1531 have been key in supporting the growth of galaxies.



26 July 2023

Webb stuns with a glowing portrait of actively forming stars

Scientists have announced yet another masterpiece taken by the James Webb Space Telescope. This time around, the space observatory has presented us with a mesmerising scene of two actively forming young stars tucked into a pocket of space about 1,470 light years away. The image showcases a striking salmon-coloured smear at its centre. This represents the area where the stars, collectively named Herbig-Haro 46/47, are found. Scientists captured everything you see here by harnessing the telescope's infrared sensors, with the fiery oranges, pale blues and textured pinks added later to enhance the frame and make it easier to glean scientific information.

You can see two conical regions of darkness on the glowing splotch's left and right sides. Imagine how the figure is actually in three-dimensions – these structures represent shadows of a gassy, dusty disc floating within the rose-coloured blob. This disc tightly surrounds the stellar duo, feeding the baby stars as they grow and mature, a process expected to culminate millions of years from the point Webb has isolated. Beyond those structures, NASA calls attention to the main event of Webb's latest muse – two huge 'lobes' peeking out on either side of the disc. The smaller right lobe falls closer to Earth, while the larger left one sits further away.

These lobes are made up of stuff from the dusty disc the stars once ingested, then later spit out into the void of space. Such ejections are considered very important in the act of star formation. You can think of them like a fountain, rapidly switching on and off to form patterns in the pool of our universe. Once these objects finish their growth period, they'll clear the scene of its chaos. In the background, you'll notice the dense symphony of stars and galaxies scattered across our universe. Some are old, some are new, some are big and others are small – but each one is equally profound to the realm we call home.

© NASA



NASA may have unknowingly found and killed alien life on Mars 50 years ago, a scientist claims

Reported by Harry Baker

A scientist recently claimed that NASA may have inadvertently discovered life on Mars almost 50 years ago and then killed it before realising what it was. But other experts are split on whether the new claims are a far-fetched fantasy or an intriguing possible explanation for some puzzling past experiments. After landing on the Red Planet in 1976, NASA's Viking landers may have sampled tiny, dry-resistant life forms hiding inside Martian rocks, Dirk Schulze-Makuch, an astrobiologist at Technical University Berlin, suggested in a 27 June article. If these extreme life forms did and continue to exist, the experiments carried out by the landers may have killed them before they were identified, because the tests would have "overwhelmed these potential microbes," Schulze-Makuch said.

This is "a suggestion that some people surely will find provocative," Schulze-Makuch said. But similar microbes do live on Earth and could live on the Red Planet, so they can't be discounted. However, others believe the Viking results are far less ambiguous. Each of the Viking landers – Viking 1 and 2 – carried out four experiments on Mars: the gas chromatography-mass spectrometry (GCMS) experiment, which looked for organic, or carbon-containing, compounds in Martian soil; the labelled release experiment, which tested for metabolism by adding radioactively traced nutrients to the soil; the pyrolytic release experiment, which tested for carbon fixation by potential photosynthetic organisms, and the gas exchange experiment, which tested for metabolism by monitoring how gases that are known to be key to life changed surrounding isolated soil samples.

The results of the Viking experiments were confusing and have continued to perplex scientists ever since. The labelled release and pyrolytic release experiments produced some results that supported the idea of

life on Mars. In both experiments, small changes in the concentrations of some gases hinted that some sort of metabolism was taking place. GCMS also found some traces of chlorinated organic compounds, but at the time mission scientists believed the compounds were contamination from cleaning products used on Earth. Subsequent landers and rovers have since proved that these organic compounds occur naturally on Mars. However, the gas exchange experiment, which was deemed the most important of the four, produced a negative result, leading most scientists to eventually conclude that the Viking experiments didn't detect life.

Schulze-Makuch believes most of the experiments may have produced skewed results because they used too much water. The labelled release, pyrolytic release and gas exchange experiments all involved adding water to the soil. "Since Earth is a water planet, it seemed reasonable that adding water might coax life to show itself in the extremely dry Martian environment," Schulze-Makuch wrote. "In hindsight, it's possible that approach was too much of a good thing."

 An artist's impression of Mars

"It seemed reasonable that adding water might coax life to show itself in the extremely dry Martian environment"

Dirk Schulze-Makuch

In very dry Earth environments, such as the Atacama Desert in Chile, there are extreme microbes that can thrive by hiding in hygroscopic rocks, which are extremely salty and draw in tiny amounts of water from the air surrounding them. These rocks are present on Mars, which does have some level of humidity that could hypothetically sustain such microbes. If these microbes also contained hydrogen peroxide, a chemical that is compatible with some life forms on Earth, it would help them further draw in moisture and also may have produced some of the gases detected in the labelled release experiment, Schulze-Makuch proposed.

But too much water can be deadly to these tiny organisms. In a 2018 study, researchers found that extreme floods in the Atacama Desert had killed up to 85 per cent of indigenous microbes that couldn't adapt to wetter conditions. Adding water to any potential microbes in the Viking soil samples may have been equivalent to stranding humans in the middle of an ocean – both need water to survive, but in the wrong concentrations it can be deadly to them, Schulze-Makuch wrote.

Alberto Fairén, an astrobiologist at Cornell University and co-scientist of the 2018 study, said that he “totally agrees” that adding water to the Viking experiments could have killed potential hygroscopic microbes and given rise to Viking's contradictory results. This is not the first time that scientists have proposed that the Viking experiments may have inadvertently killed Martian microbes. In 2018, another group of researchers proposed that when soil samples were heated up, an unexpected chemical reaction could have burned and killed any microbes living in the samples. This group claims that this could also explain some of the puzzling results from the experiments.

The SKA electronics are more radio-quiet than a smartphone on the Moon

Reported by Teresa Pultarova

New electronic devices designed to power the antennae of the world's largest radio telescope are so quiet that they'll cause less disturbance than a mobile phone on the Moon. The new electronic devices, called SMART boxes, were developed for the Square Kilometre Array's (SKA) low-frequency telescope, a network of radio dishes currently under construction in Western Australia. Together with its mid-frequency counterpart, which is being built in South Africa, the SKA-Low telescope will be the world's largest and most sensitive radio telescope once it comes online later this decade.

SKA-Low's 131,072 dipole antennae will be able to detect the faintest radio signals coming from the most distant reaches of the universe. But this exquisite sensitivity means that the array, located in a remote, barely inhabited area about 500 miles (800 kilometres) north of Perth, will be very susceptible to interference from human-made sources of radio waves. A recent study found that the telescope's antennae are so sensitive that they'll pick up even the soft hum emitted by electronics on board SpaceX's Starlink internet-beaming satellites, which orbit 342 miles (550 kilometres) above Earth. Human-made sources of radio waves could interfere with the observations and confuse astronomical research. The SKA Observatory's radio spectrum manager Federico di Vruno said that this interference could, for example, impair the telescope's search for signs of extraterrestrial life.

To minimise disruptions, a radio-quiet zone surrounds the telescope, where the use of mobile phones and radio transmitters is strictly controlled. And to make sure that the telescope's own electronics don't contribute to the problem, engineers at the International Centre for Radio Astronomy Research (ICRAR) at Curtin University in Perth developed special power and signal distribution devices that emit nearly no electromagnetic radiation.



A bubble of galaxies spanning a billion light years could be a fossil of the Big Bang

Reported by Robert Lea

Astronomers have discovered an immense bubble of galaxies that could be a fossilised remnant from the Big Bang. It's located around 820 million light years from Earth and is a staggering billion light years wide. It sits within a web of galaxies and has been given the name 'Ho'oleilana', which is a term from the Hawaiian creation chant Kumulipo. Ho'oleilana describes the origin of structure and relates to the stars and the Moon.

Massive structures such as Ho'oleilana are predicted to arise in the universe as a result of tiny ripples in the hot, dense and mostly uniform sea of matter which existed at the beginning of time. These density ripples, called baryon acoustic oscillations, grew as the universe underwent a period of rapid inflation. The ripples are also known to have given rise to major cosmic structures

while influencing the distribution of galaxies. However, this is the first identification of a single structure associated with a baryon acoustic oscillation.

The bubble itself is composed of previously identified structures that themselves have been considered some of the universe's largest arrangements of matter. This includes several superclusters, or groups of galaxy clusters, that each contain ten clusters and span up to 200 million light years. At the heart of Ho'oleilana lies the Boötes Supercluster and the Boötes Void, which is a 330-million-light-year-wide space of nothingness.

Ⓐ Around 380,000 years after the beginning of the universe, space was filled with a sea of electrons and protons

✓ Chandrayaan-3 on the surface of the Moon on 30 August 2023



India's lunar lander finds the first evidence of a moonquake in decades

Reported by Ben Turner

The lander "has recorded an event, appearing to be a natural one, on 26 August 2023," the Indian Space Research Organisation (ISRO) wrote. "The source of this event is under investigation." The Apollo missions first detected seismic activity on the Moon, which proved that the Moon had a complex geological structure hidden deep within rather than being uniformly rocky like the Martian moons Phobos and Deimos. In recent years, advanced analysis tools and computer models have enabled scientists to sift through the data gathered by Apollo and other missions and build a clearer picture of the Moon's mysterious interior.

A 2011 NASA study revealed that the Moon's core was likely made up of fluid iron surrounding a dense, solid iron ball. In May 2023, researchers used gravitational field data to confirm this iron core hypothesis, while also suggesting that blobs of the Moon's molten mantle could be separated from the rest, floating to the surface as clumps of iron and generating quakes as they went.

Magnetic fields are produced by the churning movement of material in planets' electrically conductive molten cores. Today the interior of the non-magnetic Moon is quite different from Earth's magnetised innards – it's dense and mostly frozen, containing only a small outer core region that is fluid and molten. Scientists believe that the Moon's insides cooled fairly quickly and evenly after it formed around 4.5 billion years ago, meaning it doesn't have a strong magnetic field – and many scientists believe it never did.



Webb finds an exoplanet surface that may be covered in oceans

Reported by Tariq Malik

The James Webb Space Telescope has discovered evidence of carbon-based molecules in the atmosphere of a suspected ocean world. The exoplanet, K2-18 b, is a tantalising target for astronomers as they search for life beyond the Solar System, as previous research and observations with the Hubble Space Telescope have indicated that the planet could be an ocean or 'hycean' world replete with liquid water – a vital ingredient for life. K2-18 b has a radius between two and three times larger than Earth's and is located around 120 light years away from our Solar System.

The new results showed traces of carbon dioxide and methane in K2-18 b's atmosphere without detecting ammonia, which likely indicates a water ocean under a hydrogen-rich atmosphere. "Our findings underscore the importance of considering diverse habitable environments in the search for life elsewhere," research lead author and University of Cambridge scientist Nikku Madhusudhan said. "Traditionally, the search for life on exoplanets has focused primarily on smaller rocky planets, but the larger hycean worlds are significantly more conducive to atmospheric observations."

With a mass around 8.6 times that of Earth and located in its cool star's habitable zone – the region which is neither too hot nor too cold to host liquid water – K2-18 b is an example of a planet with a size between Earth and our Solar System's ice giant Neptune. These worlds are referred to as 'sub-Neptunes' and are unlike any planets in the Solar System, which makes them something of a mystery to astronomers, who are currently debating the nature of their atmospheres. This research should help start to lift

the veil surrounding the atmospheres and environmental conditions of both sub-Neptunes and hycean worlds.

In addition to turning up carbon molecules, the Webb findings also showed the possible presence of something potentially more exciting in the atmosphere of K2-18 b. The space telescope seems to have detected dimethyl sulphide, which on Earth is only produced as a byproduct of life, mainly created by phytoplankton. The team is cautious about this detection, which is far less certain than the presence of carbon molecules. "Upcoming Webb observations should be able to confirm if dimethyl sulphide is indeed present in the atmosphere of K2-18 b at significant levels," explained Madhusudhan.

This sense of caution has to be applied to the K2-18 b findings in general when it comes to speculating about alien life. Even if the planet has a liquid water ocean and an atmosphere containing carbon molecules, that doesn't necessarily mean it harbours life or that the exoplanet could even support living things at all. With a width around 2.6 times that of Earth, the planet's size means its interior contains high-pressure ice similar to Neptune but with a thinner atmosphere and an ocean surface. This means the planet may be boiling away liquid water, making its oceans too hot to host life.

▲ An illustration of K2-18 b, now known to have carbon-based molecules in its atmosphere

➤ Artist's impression of dark matter

Dark matter 'clumps' found by tapping into general relativity

Reported by Robert Lea

Astronomers have used a principle first proposed by Einstein over 100 years ago to map the distribution of dark matter in unprecedented detail. The team's method managed to reveal the presence of dark matter 'clumps' between galaxies, showing how this mysterious substance is distributed on smaller scales. Fluctuations in the observed dark matter, identified between a distant quasar and a galaxy between that quasar and Earth, could help constrain the properties of the elusive substance.

Dark matter is troubling for scientists because, despite the fact it makes up about 85 per cent of our universe, it's effectively invisible. This is because dark matter either doesn't interact with any electromagnetic radiation, including visible light, or does so incredibly weakly. This means the particles that make up dark matter – whatever they are – cannot be atoms composed of electrons, protons and neutrons. These are the baryons that form the everyday matter that makes up stars, planets, our bodies and everything we see around us. It's this puzzle that has prompted an intense search for dark matter particles. Thus far, the only way scientists can infer the presence of dark matter is by looking at the effect it has on 'normal' matter via gravity.

We've discovered that if galaxies weren't mostly made up of dark matter, their contents would quickly fly apart as they are rotating too rapidly to be held together by the gravity of the visible matter within them. Not only are galaxies believed to be enveloped by halos of dark matter to

prevent such a catastrophe, but some dark matter models also suggest there should be clumps of dark matter inside galaxies as well as filling the space between them.

A team of researchers from Japan, led by Kindai University's Kaiki Taro Inoue, set out to use the Atacama Large Millimeter/submillimeter Array (ALMA) to better understand the distribution of dark matter around a distant, massive galaxy and find clumps of the mysterious matter in intergalactic space. To do this, they observed light from a quasar called MG J0414+0534, located 11 billion light years from Earth, by using an effect called gravitational lensing. Gravitational lensing is a concept that first emerged from Einstein's theory of general relativity, which was published in 1915. This concept differed radically from Newton's theory of gravity because it re-imagined the fabric of space and time – united as four-dimensional space-time – as a dynamic element of the universe, not just a static stage upon which cosmic events play out.

Einstein envisioned objects with mass as causing curvature, or a 'warp', in the fabric of space-time. The greater the mass, the more extreme the curvature in space-time. This can be pictured as a simple case of objects being placed on a stretched rubber sheet. A bowling ball will create a larger dent in the sheet than a tennis ball, just as a galaxy creates a larger curve in space-time than a star. Moreover, something really cool happens when a massive object of great mass comes between Earth and a distant source of light like another galaxy, or in this

case a quasar. Light would usually travel in a straight line to Earth, but when it passes this curvature in space, its path gets curved, too.

Masses closer to our planet that cause such curvature lead to more extreme deflections. This means light from a single source can take different paths around a massive object and can thus arrive at a telescope at different times. This can cause a single object to be brightened and amplified in an image or even appear at multiple places in the same image. The intervening object is therefore referred to as a gravitational lens. Gravitational lensing can help scientists see objects that would usually be far too distant and faint to observe. For example, the James Webb Space Telescope has been using gravitational lensing to great effect to see galaxies in the early universe.

But beyond helping scientists study the subject of gravitational lensing, the effect can also be used to map the distribution of matter in a galaxy acting as the cosmic lens in the first place. That includes mapping dark matter, thus astronomers have been able to map the distribution of visible matter, then infer the distribution of dark matter in lensing galaxies. Inoue and the team did this for dark matter in the galaxy lensing their distant quasar subject, causing MG J0414+0534 to appear four times in a single ALMA observation. This allowed the researchers to capture the galaxy with a higher resolution than ever before and map its dark matter down to a scale of 30,000 light years.

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FASTER THAN THE SPEED OF LIGHT

The speed of light is the universe's ultimate speed limit, but could there be a way to get around it?

Reported by Giles Sparrow

Pick up any book on physics or astronomy and you'll read that light is the fastest thing in the universe and that immutable laws prevent anything else from ever matching its speed through space. The limited speed of light sets the rules of cause and effect across the universe, and even affects how we see the distant cosmos. But what are the rules behind this cosmological speed limit? How exactly does it apply? Could there be natural phenomena that break this apparently universal rule, and might we one day find a way of doing the same?

Light travels through an empty vacuum with astonishing speed, crossing 299,792 kilometres (186,282 miles) of empty space in a single second. This means that light – and other related forms of electromagnetic radiation such as radio waves – seems to move instantaneously; it's only when we look into the depths of space that the effects of its finite speed become apparent. Radio commands sent to rovers on Mars may take up to 20 minutes to reach the Red Planet, while light from the nearest stars has travelled several years to reach us. Distant galaxies are hundreds of millions and even billions of 'light years' away.

The idea of the speed of light as an ultimate cosmic speed limit only emerged around 1905 through Albert Einstein's special theory of relativity. "We'd had, at that point in the early 20th century, a fairly complete theory of classical electromagnetism for about 40 years or so," explains Dr Erik Lentz, a physicist at the Pacific Northwest National Laboratory (PNNL) in Washington. "And so Einstein had a notion of how electromagnetic fields could create a propagating light beam that travelled at a particular speed. But that speed, interestingly, didn't seem to depend on what frame of reference you calculated it from. Whether someone was trying to measure the speed of a light beam relative to themselves in a laboratory or on board a moving train, it didn't seem to matter."

Einstein's special theory described how this fixed or 'invariant' speed of light can affect other types of measurements, usually in circumstances where two objects are moving at very high or 'relativistic' speeds in relation to each other. For instance, objects moving at high speeds relative to an outside observer appear shortened along their direction of travel, experience time dilation and even increase their mass rather than

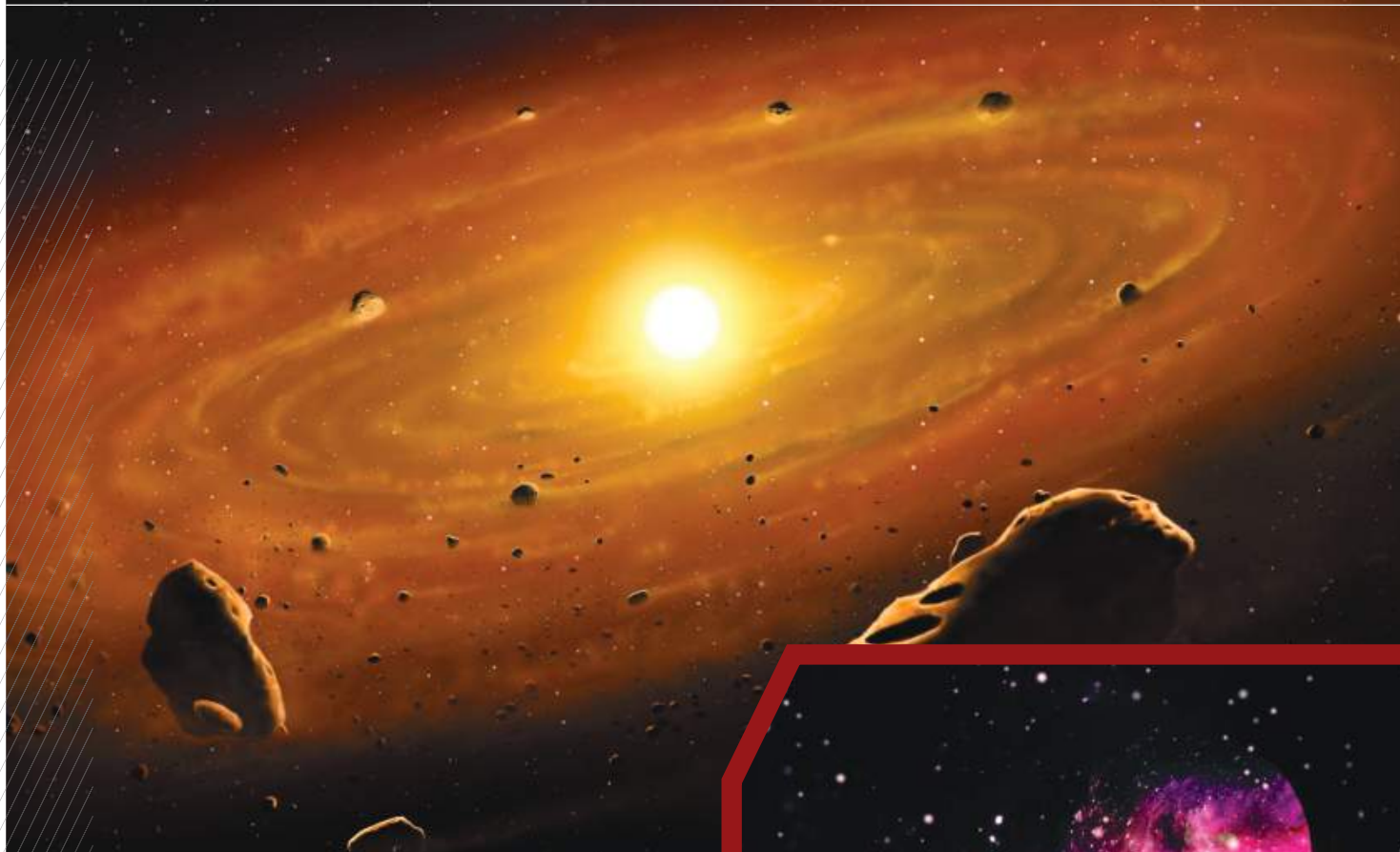
FASTER-THAN-LIGHT PARTICLES?

The laws of relativity make it impossible for matter particles to reach the speed of light, but they don't rule out the idea of particles that naturally exist on the other side of this barrier. Some physicists argue there could be a whole universe of such faster-than-light particles, known as tachyons. They would have very unusual properties compared to normal matter. For instance, their speed would decrease as their energy increased, and it would take an infinite amount of energy to slow them down to the speed of light.

But most scientists remain doubtful. Some argue that the existence of tachyons would offer a way around the fundamental rule of cause and effect. This is because from our point of view tachyons could theoretically carry signals backwards in time, giving rise to all sorts of paradoxes.



© Getty/Argonne National Laboratory



their velocity as they attempt to reach the speed of light. These factors all increase exponentially as an object gets closer and closer to the speed of light, making it impossible for any object with mass to actually travel at the speed of light relative to another frame of reference – light itself can only do so because it's a massless electromagnetic wave.

But the special theory is just part of the story. As the name suggests, it only applies to movement in certain situations, namely those where objects are neither accelerating or decelerating. Einstein's general theory of 1915 expanded to take in a wider range of scenarios and also to tackle the effects of gravity, which can be treated as a form of acceleration. One consequence was that movement in time and the three previously rigid dimensions of space could be better considered in terms of a more flexible four-dimensional structure known as space-time. "In the generalised form of relativity, those principles started to become localised," expands Lentz. "You had to change your statement from 'no two things can travel faster than the speed of light' to 'no two things moving relative to each other at a particular point in space can move past each other faster than the speed of light. But once you start to think about separating two bodies, then those statements no longer become exactly relevant. You can use the dynamics of space-time in order to change the separation of those bodies at potentially arbitrary speed.'"

For an example familiar to many space enthusiasts, consider looking out across billions of light years into the depths of intergalactic space. We've known for almost a century that the universe is rapidly expanding, and that the further away a distant galaxy

is, the faster it tends to be moving away from Earth. This effect is mostly due not to the motion of galaxies through space, but to the expansion of space between them ever since the Big Bang. Each unit of space itself is growing at a more or less uniform rate, and so more widely separated objects, with a greater amount of space between them, are driven apart more rapidly. From our point of view, this means that beyond a certain distance, galaxies will be moving away faster than the speed of light. However, because this means their light can never reach Earth, such objects lie forever beyond our 'observable universe'.

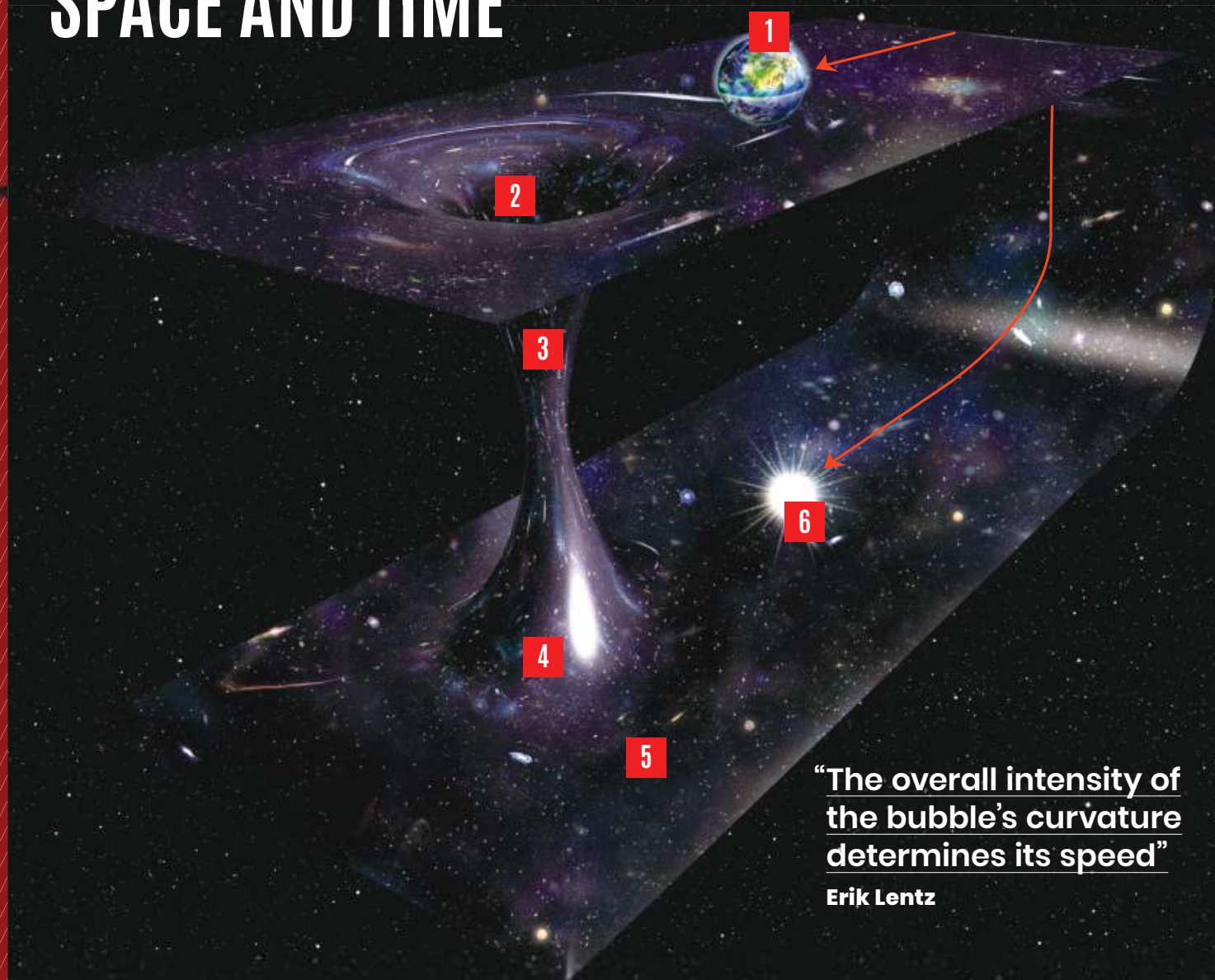
For many people, however, the question of breaking the light-speed barrier is a more practical one: could humans – or indeed extraterrestrials – ever hope to find a means of faster-than-light travel to bridge the vast distances between stars and galaxies? If the only concern is for the length of the journey from the crew's point of view, then relativity already provides a solution in the

B Shortly after the Big Bang, a vast release of energy blew up space in an event called inflation

A Wormholes connecting different parts of the universe offer a potential means of travelling faster than light



TRAVELLING THROUGH SPACE AND TIME



“The overall intensity of the bubble’s curvature determines its speed”

Erik Lentz

1 Home near a wormhole

To allow for truly convenient interstellar travel, a wormhole would have to be located – or created – quite close to Earth, otherwise it would take many years to reach in the first place.

2 Down the funnel

The mouth of a wormhole forms a steep-sided ‘gravity well’, but there’s a safe entrance that avoids crossing the event horizon.

3 Through the gap

Crucially, the passage through the wormhole is ‘open’ – it forms a broad cylindrical tunnel so that the crushing gravity of the central singularity can be avoided.

4 Not-so-short cut?

The trip might be shorter, but it’s still not instantaneous. Because going through might still involve near-light speeds, effects such as time dilation would make the journey seem shorter.

5 Safe passage

In theory, it’s possible to steer a passage that hugs the outer edge of the wormhole to emerge at the other end.

6 Other places and times?

The other end of the wormhole emerges near a distant star. Depending on exactly how the universe works, it might even form a tunnel through the fourth dimension of time as well.

form of time dilation. As seen from outside, time for a fast-moving spaceship will appear to flow much more slowly; a trip to a nearby star might be accomplished in a matter of weeks, or even less, and the crew might at first think they'd travelled faster than light. Upon arrival at their destination, however, they'd be able to measure how much time had passed for the rest of the universe.

A more fantastical form of 'true' faster-than-light travel might be a wormhole across space-time – a tunnel linking one area of the universe to another via a cosmic shortcut. Wormholes are a popular concept in science fiction and can, at least in theory, arise naturally according to the laws of relativity. For instance, they might form when a massive, superdense object distorts the space around it to create a 'gravitational well' in the fabric of space-time that connects to a similar well in another location. Some cosmologists have speculated that tiny natural wormholes could riddle the universe, but creating an artificial one with a wide enough tunnel for spacecraft to fly safely through would represent a huge challenge for even the most advanced cosmic civilisation – and a single wormhole could only link two locations.

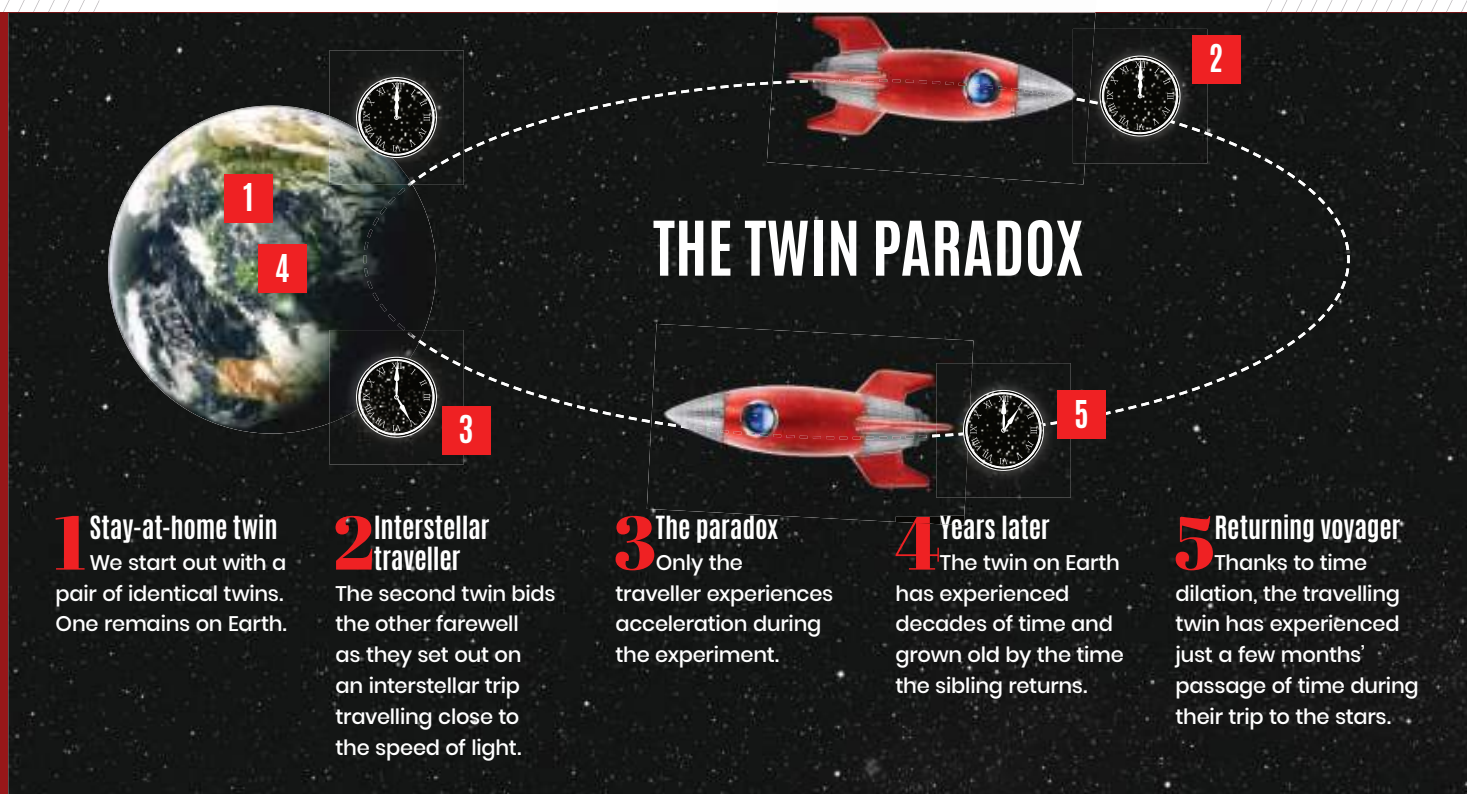
Perhaps the most intriguing and versatile form of faster-than-light travel is the warp drive. More than a little reminiscent of the technology used by the USS Enterprise and many other science-fiction starships, a warp drive creates a distorted bubble of space that can move through its surroundings at faster-than-light speeds while carrying a spacecraft in a relatively normal region of space embedded within it. Lentz traces the origins of the idea back to the work of Mexican physicist Miguel Alcubierre in the 1990s. Alcubierre took inspiration from the theory of

inflation – an early cosmic growth spurt that followed the Big Bang, during which the universe briefly expanded far faster than the speed of light, pushing the bulk of the newborn cosmos forever beyond our view. "There was this precedent in cosmology for thinking about objects that could separate at a very high rate from one another," recounts Lentz. "And so Alcubierre constructed this space-time geometry. He engineered, in a theoretical way, a space-time metric to create a localised region, or bubble, with a spherical shape. And this entire spherical region could move through space-time at an arbitrary speed while maintaining in its centre a region of locally 'flat' space-time – a nice, calm space where you could put an observer inside a relatively unobtrusive spacecraft."

In Alcubierre's concept, space behind the warp bubble would expand at inflation-like, faster-than-light speeds, while space in front would be contracted at a similar rate, propelling the bubble forwards. "The observer wouldn't necessarily feel any

"This spherical region could move through space-time at an arbitrary speed while maintaining in its centre a region of locally 'flat' space-time"

Erik Lentz



A PRACTICAL WARP DRIVE?

Led by physicist Harold G. White, a team at NASA's Advanced Propulsion Physics Laboratory in Houston, Texas, has been steadily working on turning the warp drive into a reality. As well as building instruments to measure the tiny distortions of space-time that might be generated by a laboratory-scale device, White and his colleagues have worked on the design of devices to generate warp fields. Their latest designs use a doughnut-shaped ring to contain a rapidly oscillating energy field.

Inward effects of the field cancel out to keep the bubble of space inside flat.

The crewed vehicle sits safely inside the flat space created by the drive.

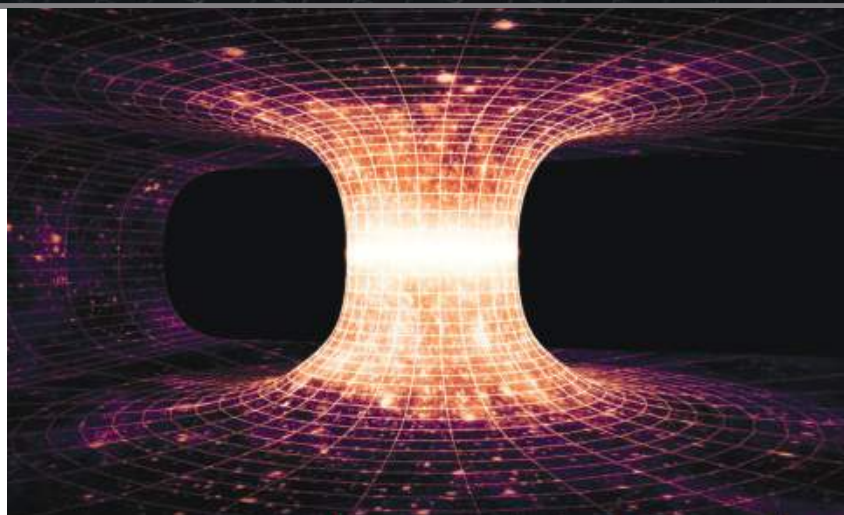
A ring-shaped torus generates an oscillating energy field.

Space compresses ahead of the bubble.

Outward effects soften and distort space around the vehicle.

sensation of motion," Lentz points out, "but afterwards they would have this notion that they started at point A and ended at point B, and the rate at which the observer travelled between them indicated that they had moved faster than light."

By moving an area of space-time complete with its contents rather than accelerating a specific object, the Alcubierre warp drive overcomes many problems presented by relativity and light's speed limit. But there are major challenges to turning this neat theoretical idea into reality. Perhaps the most immediate is how to construct the bubble in the first place, and the fact that in order to retain a stable shape it must have a negative energy density in comparison to the space around it. At first this might sound impossible. Space-time naturally carries a very small amount of positive 'vacuum energy', but laboratory experiments have generated small regions with even lower energy densities, which are therefore 'negative' compared to their surroundings. The challenge lies in creating negative



energy on a much larger scale, and early calculations suggested this would require harnessing more energy than is present in the entire observable universe.

"There has been follow-up work after Alcubierre put out his paper to try and bring this number down," Lentz points out. "And there's been a decent amount of success, but it still requires the manipulation of negative energy equivalent in magnitude to that of a small asteroid." That is, the energy that would be released if that asteroid's entire mass could be transformed into pure energy. "And again, with the Alcubierre-like solution,

Massive objects create dents in space-time – distortions that we experience as gravity. A wormhole is a hypothetical bridge formed when two of these dents in different parts of space connect

we still have a problem of a sort in terms of whether or not we're even able to make the more exotic negative energy media."

In 2020, while working at Germany's Göttingen University, Lentz found himself drawn back to the problem, paving the way for a potential new solution. "Every single one of these warp drive papers using general relativity seemed to require this exotic negative energy density in one form or another. I wanted to see if you could change that, if you could try and make a solution in the context of general relativity that could travel at arbitrary speed – meaning either below or possibly above the speed of light – that didn't require exotic media, or at least it didn't require negative energy. And after a bit of work, I believe I came up with such a solution."

Lentz's version of the warp drive creates a bubble within a moving wave-like structure in space-time, rather than Alcubierre's simple sphere. "It had many more subdomains to it," he recalls, "and the sourcing function – where the mass and energy would need to be and the shapes that they would need to be configured in – was also a bit more complicated than Alcubierre's original solution. But by exploring this larger and more complex set of space-times, which involved a lot of trial and error, I found some geometries that appeared to do the job."

By flipping the energy density required in the distorted space from negative to positive, Lentz's work seems to make the construction of a warp drive far more plausible – but how exactly would it work? For instance, how could the speed of movement be controlled? "The overall intensity of the bubble's curvature determines its speed," explains Lentz. "So you can make a bubble that's relatively non-intense and would travel at a slow

speed – much slower than the speed of light, which I think is how any experimental verification would happen. You'd make a very low-intensity version of a bubble to demonstrate that this sort of manipulation of space-time can occur in a laboratory setting long before you'd think of making a functional warp drive for a spacecraft."

While Lentz's new role at PNNL has drawn him away from work on warp drives, his breakthrough has already inspired other physicists to revisit the idea with fresh approaches, and he's keen to return to the area in the future himself to resolve some unanswered questions. In particular, passing through the light-speed barrier seems to generate a 'horizon' – a communication barrier sealing off the region being transported from the rest of the universe. "If there is a horizon, how would you communicate with the rest of the bubble in order to bring your speed up or down?" he ponders. It's certainly an intriguing idea. We might one day be able to cross the universe faster than the speed of light, but be unable to put it to practical use because we can't reach the brakes.

Giles Sparrow

Space science writer

The author of over 20 books on popular science, Giles holds a degree in astronomy and is an editor specialising in science and technology.

🔴 The most distant galaxies we can see are moving away from us at speeds approaching the speed of light thanks to cosmic expansion



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FUTURE TECH

SPACE HOTELS

Have you achieved all your travel goals on Earth? If so, a space-based outpost could be your next trip

After Apollo 8 made the first flight around the Moon during Christmas 1968, Pan American Airways opened a waiting list for a planned service to the Moon. Over 93,000 people signed up for the list, and it only closed when Pan Am folded in 1991. While this early optimism failed to deliver, there are now a number of projects working towards private space stations, and they do have space tourism and space hotels as part of their plans. One of the biggest leaders was Bigelow Aerospace of Las Vegas, funded by a hotel billionaire, before its closure in 2021.

Robert Bigelow made his fortune building the Budget Suites of America chain of hotels. Interested in space technology since childhood, he started Bigelow Aerospace in 1999 to take on a NASA concept for inflatable space modules that had been cancelled in the early 1990s. Bigelow's intention was to build, operate and sell access to private space stations using these inflatable modules. The company launched its first test crafts, Genesis I and II, into space in 2006 and 2007. Though it subsequently pursued ground testing while waiting for private access to space to develop, Bigelow went full circle and launched its first piloted module for NASA to bolt on to the International Space Station (ISS) in 2016.

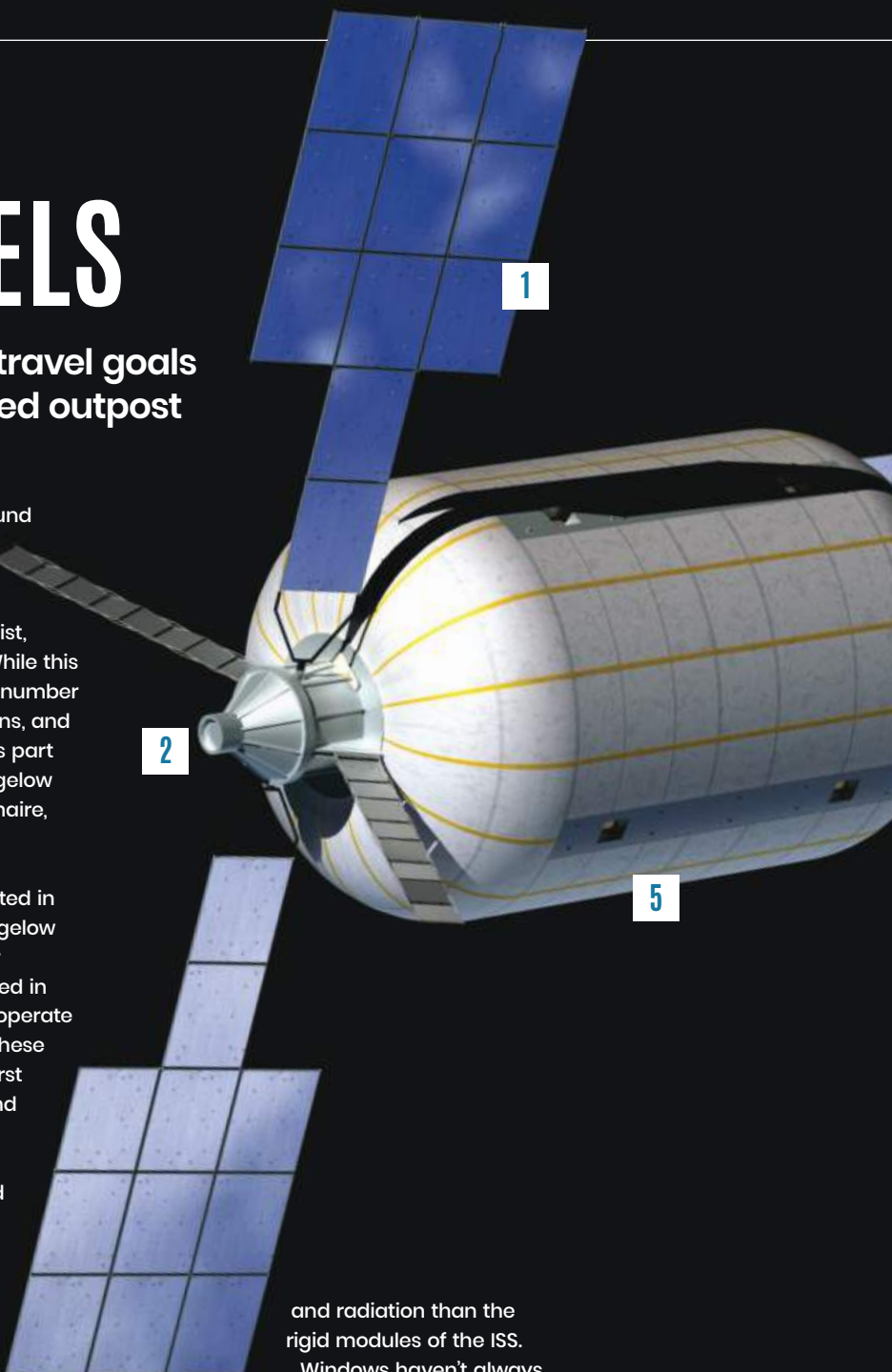
In the long term, Bigelow intended to launch modules that would be packed into a rocket's nose cone and then inflated once in orbit. Bigelow had official expressions of interest from seven different countries, including the UK, about accessing these facilities once they were in place. But because the access was privately arranged for profit, there's now interest in using modules like these for space tourism, so we could see the first space hotel in the near future.

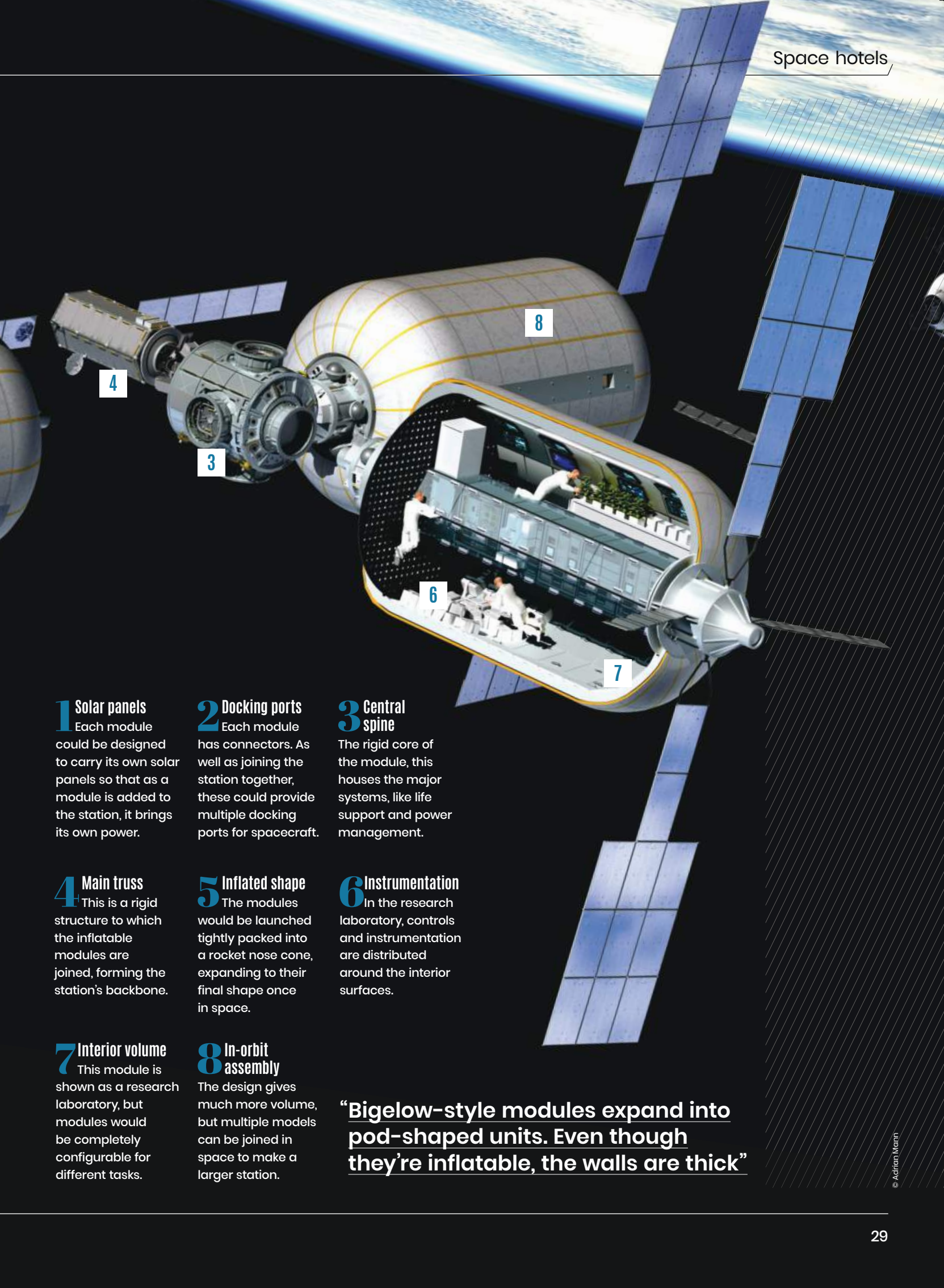
While the now-defunct company won't conquer outer space, Bigelow's space hotel concept could still live on, where it would make use of existing resources. A SpaceX Dragon capsule could launch tourists into the outer atmosphere. With careful timing you could catch up with a space station hotel in only a few orbits. After docking, you would float out of your seat and drift into the core of your module. Bigelow-style modules expand into pod-shaped units. Even though these are inflatable, the walls are thick, made of multiple layers of ballistic, thermal and radiation protection. Despite being a balloon, it can provide greater protection against debris

and radiation than the rigid modules of the ISS.

Windows haven't always been a designer's first

thought – the Project Mercury astronauts had to demand one and the US Skylab station only got a small porthole – but these inflatable modules could have large ultraviolet-shielding windows. The view is just as important for researchers as tourists, though these categories will probably overlap. There have been eight tourist flights to the ISS, but the participants have always chosen to carry out work of some kind – certainly, it will be a while before anyone feels they just want to float by the window after spending that much money. In the future there could be multiple stations built of Bigelow-style modules, and they could even provide habitation for flights to Mars and the Moon.



**1 Solar panels**

Each module could be designed to carry its own solar panels so that as a module is added to the station, it brings its own power.

2 Docking ports

Each module has connectors. As well as joining the station together, these could provide multiple docking ports for spacecraft.

3 Central spine

The rigid core of the module, this houses the major systems, like life support and power management.

4 Main truss

This is a rigid structure to which the inflatable modules are joined, forming the station's backbone.

5 Inflated shape

The modules would be launched tightly packed into a rocket nose cone, expanding to their final shape once in space.

6 Instrumentation

In the research laboratory, controls and instrumentation are distributed around the interior surfaces.

7 Interior volume

This module is shown as a research laboratory, but modules would be completely configurable for different tasks.

8 In-orbit assembly

The design gives much more volume, but multiple models can be joined in space to make a larger station.

“Bigelow-style modules expand into pod-shaped units. Even though they’re inflatable, the walls are thick”

BIO+

Dante Lauretta

Lauretta is a professor of planetary science and cosmochemistry at the University of Arizona's Lunar and Planetary Laboratory. He is also the principal investigator of NASA's OSIRIS-REx (Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer) mission. He received a BS in physics and mathematics and a BA in oriental studies, with a focus in Japanese, from the University of Arizona in 1993, and a PhD in Earth and planetary sciences from Washington University in St Louis in 1997. Lauretta is the recipient of the 2002 Nier Prize of the Meteoritical Society and the 1995 Ninninger Meteorite Award.



Dante Lauretta

“I really thought we might be in trouble”

On 24 September, NASA's OSIRIS-REx spacecraft will drop off a piece of space rock from asteroid Bennu at Earth. Ahead of the historic sample landing, we catch up with Dante Lauretta, the mission's chief scientist, to learn about the obstacles that nearly thwarted the mission

Interviewed by Tereza Pultarova

OSIRIS-REx is about to deliver a piece of asteroid Bennu to Earth on 24 September. The mission launched in 2016 and spent two-and-a-half years studying Bennu from orbit. How much has the mission changed our understanding of asteroids?

OSIRIS-REx rendezvoused with asteroid Bennu in December 2018, and right away I knew that we were in for a real challenge. Even though we had done an extensive astronomical campaign to characterise this asteroid, we really had some major surprises. Most importantly, when we looked at the thermal data, the asteroid surface heats up and cools down really quickly, which we interpreted as fine-grained material, kind of like a beach. In fact, I used the word beach repeatedly when I was describing the surface earlier in the mission concept.

Instead we saw something that was covered with large, rough and rocky boulders everywhere, and there were no smooth areas of the kind that we designed the spacecraft to go down and sample. It also became really apparent that [Bennu] is not a solid body. It is actually what we now term a rubble pile, and it seems that most small asteroids are this kind of object – very loose accumulations of boulders and dust and gravel probably formed after a giant catastrophic collision in the main asteroid belt hundreds of millions of years ago.

Are you saying that you designed the mission with a wrong assumption of how the asteroid would look? Was there a real risk that you might not be able to touch down and collect the sample?

When we designed the spacecraft, we had a design targeting accuracy of about 50 metres [164 feet]. We based that knowledge on a prior mission from the Japanese Aerospace Exploration Agency called Hayabusa, which was the first spacecraft to rendezvous with one of these small objects. This asteroid had nice, wide smooth patches, and we thought that Bennu must be more benign than Itokawa. We were really using that prior knowledge to drive our concept for getting

✓ OSIRIS-REx launched on 8 September 2016 aboard an Atlas V



© NASA / Getty



A Laurretta and his colleagues at a rehearsal for the sample-recovery part of the mission

to this asteroid, and the telescoping data seemed to confirm that. The thermal properties, also the radar properties, really looked like a smooth surface, so when I first saw that, I really thought we might be in trouble there.

How did you go about this challenge, trying to find a landing spot on this very rocky asteroid surface?

When you launch a spacecraft, the only thing you can fix is the software, so we had to make the spacecraft smarter. When we launched, we planned to use a laser altimeter for the guidance down to the asteroid because we were expecting these big, smooth areas. We just thought that we would need to know that we were coming down at the right rate towards the surface. Instead we had to completely change the strategy, using the onboard cameras and performing an extensive mapping campaign, sometimes mapping features as small as a couple of centimetres to put into the spacecraft's memory so that it could make real decisions and guide itself down to the safe location, which turned out to be only ten metres [33 feet] across. Even in that area, there were still hazards – spacecraft-killing boulders. We taught the spacecraft where they were and what they looked like, and if the spacecraft determined it was coming down on a boulder it would actually reverse engines and fly away and come back and try to sample another day.

When you were going through this process of finding a suitable location on the surface of the asteroid, you had a very surprising collaborator in Sir Brian May,

who is known worldwide for his music as a member of the legendary rock band Queen. What work has he done for the team?

Brian is an expert in producing stereo images along with his collaborator Claudia Manzoni. We didn't plan on stereo imaging. We didn't design a stereo camera, but [May] was able to find pairs of images that have just the right angular separation. When he corrected for the shadows and the alignment and when you look at them through the stereoscope, all of a sudden the surface appears to you in this brilliant three-dimensional view and you get a real understanding of how rough and rugged the surface is. And he embraced the challenge and really helped us out.

It almost sounds as if Brian May rescued the OSIRIS-REx sampling attempt.

Brian and Claudia both played a critical role in sample site selection. We are very grateful for their efforts, and absolutely – they opened our eyes to the true nature of the surface.

The challenges didn't end with selecting the landing site. When you touched down, something happened. Remind us, what happened there and what did that teach you about asteroids?

What happened was very different from our early concept animations of the sampling. The device is called TAGSAM, the Touch-and-Go Sample Acquisition Mechanism. It's about 30 centimetres [11 inches] in diameter and it's basically an air filter. We blow down gas, kind of like a leaf blower designed to push the material into that sample-collection chamber. You can tell that we thought the surface was going to be nice and hard and provide resistance to the downward motion of the spacecraft. We thought that we would just collect a surface level of gravel and dust. Instead, the surface of Bennu, which I call the trickster asteroid, responded kind of like dropping into a pool of water. There was absolutely no resistance to the downward

motion of the spacecraft. We made contact at ten centimetres [four inches] per second. One second we were ten centimetres down into the surface, and we continued to push down about 50 centimetres [20 inches] deep. Thankfully, the backaway thrusters still fired and we were able to safely retreat from the surface with our precious cargo in hand.

Based on your experience with Bennu and OSIRIS-REx, do you have an idea what would have happened if an asteroid like Bennu were the target of the Double Asteroid Redirection Test (DART) mission?

The DART mission was a huge success. That was NASA's first attempt at planetary deflection using a kinetic impactor to change the velocity of an asteroid – the same kind of technology we would like to employ if there was a real asteroid threat. When I saw the images of Dimorphos, which is a satellite of a larger asteroid, it looked really familiar. It looked like a bouldery pile of rubble, more shaped like an American football than Bennu, but still that same kind of characteristic texture. The mission was phenomenally successful. It imparted a lot of momentum to the asteroid, substantially slowed its orbital velocity, and a large part of that is because there was so much material that was ejected from the surface; that transfer of energy resulted in a significant change of the orbital period.

I guess that's important because Bennu might in the future be a target of such a deflection mission for real... is that right?

Yes. Bennu is known as the most potentially hazardous asteroid in the Solar System. I don't want people to panic – the odds are still low, about 0.05 per cent – but if an impact is going to occur it will be in the year 2182. We have a lot of time, and we are now starting to develop the technologies and strategies [to deal with this threat]. I think that people of the future will be well-equipped to deal with Bennu, especially because of the enormous amount of information that we have collected. I like to think of it as one of our gifts to the future generations.

OSIRIS-REx will deliver its precious piece of asteroid Bennu to Earth in September. How are you preparing for this big moment?

It's kind of a culmination for me of almost 20 years of my career, getting ready for this big event on 24 September. The spacecraft is on its journey to Earth. It's getting closer every day. About four hours before it hits the top of the atmosphere, it will release the sample-return capsule, which is about 80 centimetres [30 inches] in diameter and looks like a mini version of the capsule that astronauts come back from space in. The spacecraft will then fire its engine and continue to orbit the Sun. The capsule will hit the top of the atmosphere at 27,000 miles per hour, or about 12.4 kilometres per second, and it will parachute into the Utah desert in the southwestern US.

We have been rehearsing and practising. We have to interface with the US military because it's their land

that we're coming in on and we've been going out and doing the exact same procedure that we expect to do on the event. We have built a beautiful clean room at NASA's Johnson Space Center to receive the samples, and we've done a lot of rehearsing. My science team gets 25 per cent of the sample, but we've never really defined which 25 per cent. How do you define the 25 per cent? We've been going through a lot of decision making, scenarios and rehearsals, tensions. What is it going to be like if everybody wants the same thing? Kind of to get that out of the way so that by the time we are doing this for real, I know I will be in a highly emotional state. You want to have that muscle memory. You just want to go on autopilot; you want to know what to do. You've got a job, get it done and then the real holiday begins. We want to get these samples into our laboratory, the ones that we have been dreaming about since 2004.

When do you think we can expect the first science results from the sample?

I am advocating for it as quickly as possible. If everything goes according to plan, we will have the science canister opened up on day two. This is the protective aluminium shell where TAGSAM and the sample are contained. One of the other surprises that we had was when we backed away and we looked at the sample collector, there was material that was escaping, so we kind of went into an emergency mode to quickly stow [the sample]. I think there is going to be dust all over the inside of this canister, and our plan is to sweep it on day two. We have a set of amazing instruments in Houston, and I think we are going to have information within a few days, at least the basic understanding – did we get back what we expected or will Bennu continue to surprise us?



✓ The mission was monitored closely and amended throughout to increase its chance of success

✗ The spacecraft was built by Lockheed Martin in partnership with NASA

FOCUS ON

A RARE IRON METEORITE COULD REVEAL THE SECRETS OF THE EARLY SOLAR SYSTEM

The sample is the first piece of iron space rock from a parent body with a known orbit

Reported by Robert Lea

Scientists have studied a rare iron meteorite in detail, discovering what orbit its parent body occupied before crashing to Earth. The 14-kilogram chunk fell to Earth after a fireball erupted over Sweden in 2020. Iron meteorites such as this constitute only around two per cent of the space rocks that make it to Earth's surface, so the object became a rare and valuable sample.

Iron meteorites are believed to be fragments of molten metallic cores at the hearts of planetesimals, small bodies that existed around 4.5 billion years ago. Many of these bodies came together to form the Solar System's planets. As such, studies of meteorites like this can reveal valuable information about the state of the Solar System in its infancy and the sorts of elements that ended up becoming incorporated into the planets.

"An excellent opportunity for research occurred when a bright fireball over Sweden produced the first iron meteorite with a possibility to derive its pre-atmospheric trajectory," Jaakko Visuri, an analyst with the Finnish Fireball Network and Ursa Astronomical Association, said. "This provided us a unique chance to study the delivery mechanism of iron meteorites and look for iron-rich reservoirs in the Solar System."

Seizing this opportunity was a team of astronomers from Ukraine, led by Irina Belskaya, head of the Department of Physics of Asteroids and Comets at Kharkiv National University's Institute of

Astronomy. The research was conducted as part of a project started in 2020 dedicated to studying metal-rich asteroids, which are the parent bodies of iron meteorites. "For the very first time, this discovery presents a documented trajectory of an iron meteoroid, showcasing a record-breaking fireball descent at a mere seven miles [11.4 kilometres] above Earth's surface and also unravelling the celestial pathways it traversed before gracing our planet," said Finnish Geospatial Research Institute researcher Maria Gritsevich.

Meteoroids are small space rocks; they become meteors when they hit Earth's atmosphere and burn up. Pieces of these rocks that make it to Earth's surface are called meteorites. "This achievement not only provides insights into the remarkable journey it endured, but also contributes to our understanding of the origins and dynamics of iron-rich space objects, thereby deepening our insight into the broader Solar System," Gritsevich added.

Among the information the scientists collected about the meteorite were clues about the conditions and processes that led to its formation. This could help determine how chemical resources are distributed through the Solar System. Such work could potentially help prepare future space missions that go out on the hunt for metal-rich asteroids, which could be enticing space-mining targets.

Calculating the orbit of the meteorite's parent body helps paint a picture of the celestial mechanics at play in the early Solar System, including interactions between other bodies in our cosmic backyard and the gravitational forces at play. In addition, better predicting the path of this object could help constrain the orbits of other asteroids, with implications for planetary defence. As such, this small iron-rich rock from space could become a stepping stone for a wealth of future space science.

1 Shapeless cloud

About 4.5 billion years ago, the raw materials of the Solar System lay in a shapeless cloud of gas and dust. Its dominant components were hydrogen and helium, but it was also enriched with elements created by previous generations of stars and scattered through the so-called interstellar medium. These included carbon, oxygen and nitrogen, as well as dust grains up to one micrometre across.

2 Collapse begins

The trigger event for the formation of an emission nebula typically produces condensation in several regions of the cloud that happen to have higher densities. Each may give rise to a whole group of stars – once the first stellar heavyweights have begun to shine, their radiation helps energise the nebula, and also sculpts its shape.

3 Individual systems

A single globule of collapsing gas and dust may give rise to a single star or a multiple star system at its centre. As material falls inwards, collisions between gas clouds and particles tend to cancel out movements in opposing directions, while an effect known as the conservation of angular momentum causes the cloud's central regions to spin faster.

9 The Solar System today

The near-circular orbits of the planets are an inevitable result of their formation from the merging of many objects in a disc around the Sun. While many solar systems around other stars seem to have planets in much wilder orbits, this is probably a result of later gravitational interactions and phases of planetary migration, like those that once shaped our own Solar System.

8 Planetary migrations

During one or more phases of planetary migration, the giant planets of the outer Solar System changed their configurations and locations, moving back and forth through a host of smaller bodies. The havoc ultimately gave rise to the modern asteroid belt, Kuiper Belt and Oort Cloud, though the latter may also include comets captured from other stars born alongside the Sun.

7 Growing pains

As the new protoplanets continued to orbit, their gravity drew in huge numbers of pebbles and they grew rapidly. In our inner Solar System, where material was limited, they reached the size of Mars – Earth and Venus subsequently formed from collisions between several such worlds. In the outer Solar System, copious ice allowed them to reach the size of Uranus.

THE BIRTH OF THE PLANETS

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4 Flattening disc

The end result of the cloud's collapse is a spinning disc with an orientation derived from the slow, random rotation of the original globule. Dust and ice particles tend to concentrate more efficiently around the central plane of this disc, while gas forms a looser halo and continues to fall in towards the central regions until conditions there become extreme enough to create one or more protostars.

5 Protoplanetary system

A few million years after the initial cloud began to collapse, nuclear fusion ignited in the central star, and most of the excess gas had disappeared – either dragged in by the star's gravity or ejected in bipolar jets along the system's axis of rotation. What remained was closer to the plane of the Solar System, and it too was gradually driven away by our star's radiation.

6 Planets from pebbles

Within the nebula, the seeds of planets started to form – according to the latest theories, these were huge drifts of pebble-like particles herded together by turbulence in the surrounding gas. They clustered into huge streams to reduce the headwinds they encountered. Eventually, these pebble clouds grew massive enough to collapse under their own gravity, forming protoplanets up to 2,000 kilometres (1,240 miles) across.

INSTANT EXPERT

IF HUMANS WENT EXTINCT, WHAT WOULD EARTH LOOK LIKE A YEAR LATER?

Have you ever wondered what the world would be like if everyone suddenly disappeared?

If humans disappeared from the world, and you could come back to Earth to see what had happened one year later, the first thing you'd notice wouldn't be with your eyes... it would be with your ears. The world would be quiet. And you would realise how much noise people make. Our buildings are noisy. Our cars are noisy. Our sky is noisy. All of that noise would stop. After a year without people, the sky would be bluer, the air clearer. The wind and the rain would scrub clean the surface of Earth; all the smog and dust that humans make would be gone.

Imagine that first year, when your house would sit unbothered. Inside your house, no water would be in your faucets. Water systems require constant pumping. If no one's at the water supply to manage the machines that pump water, then there's no water. But the water that was in the pipes when everyone disappeared would still be there when the first winter came. On the first cold snap, the frigid air would freeze the water in the pipes and burst them. There would be no electricity. Power plants would stop working because no one would monitor them and maintain a supply of fuel. Your house would be dark, with no lights, TV, phone or computer. Your house would be dusty. There's dust in the air all the time, but we don't notice it because our air-conditioning systems and heaters blow air around. As you move through the rooms in your house, you keep dust on the move too. But once all that stops, the air inside your house would be still and the dust would settle all over.

The grass in your garden would grow until it got so long and floppy it would stop growing. New weeds would appear, and they would be everywhere. Lots of plants that you've never seen before would take root. Every time a tree drops a seed, a little sapling might grow. No one would be there to pull it out or cut it down. You'd notice a lot more bugs buzzing around. People tend to do everything they can to get rid of bugs: they spray the air and the ground with bug spray, remove habitats, put screens on windows. And if that doesn't work, they swat them. Without people doing all these

things, the bugs would come back. They would have free rein of the world again. Critters would wander around. First the little ones: mice, groundhogs, raccoons, skunks, foxes and beavers. Bigger animals would come later – deer, wolves and the occasional bear. Maybe not in the first year, but eventually.

With no electric lights, the rhythm of the natural world would return. The only light would be from the Sun, the Moon and the stars. The night critters would feel good they got their dark sky back. Fires would happen frequently. Lightning might strike a tree or a field and set brush on fire, or hit the houses and buildings. Without people to put them out, those fires would keep going until they burned themselves out. After just one year, the concrete stuff – roads, highways, bridges and buildings – would look about the same. Come back, say, a decade later, and cracks in them would have appeared with little plants wiggling up through them. This happens because Earth is constantly moving. With this motion comes pressure, and with this pressure comes cracks. Eventually, the roads would crack so much they would look like broken glass, and even trees would grow through them.

Bridges with metal legs would slowly rust. The beams and bolts that hold the bridges up would rust too. But the big concrete bridges and the highways, also concrete, would last for centuries. The dams and levees that people have built on the rivers and streams of the world would erode. Farms would fall back to nature. The plants we eat would begin to disappear. Not much corn, potatoes or tomatoes anymore. Farm animals would be easy prey for bears, coyotes, wolves and panthers. And pets?

➦ Nature would reclaim the empty towns and cities if humans vanished

BIO CARLTON BASMAJIAN

Basmajian is an associate professor of community and regional planning at Iowa State University, where he studies the history of urban and regional planning in the United States. He holds a bachelor's degree from the University of Chicago, a master's degree from the Georgia Institute of Technology and earned his PhD at the University of Michigan in 2008.



Crust



The cats would go feral – that is, they would become wild, though many would be preyed upon by larger animals. Most dogs wouldn't survive, either.

In a thousand years, the world you remember would still be vaguely recognisable. Some things would remain; it would depend on the materials they were made of, the climate they're in and just plain luck. An apartment building here, a cinema there or a crumbling shopping mall would stand as monuments to a lost civilisation. The Roman Empire collapsed more than 1,500 years ago, yet you can see some remnants even today. If nothing else, humans suddenly vanishing from the world would reveal something about the way we treated the Earth. It would also show us that the world we have today can't survive without us and that we can't survive if we don't care for it. To keep it working, civilisation – like anything else – requires constant upkeep.

THE MAKING OF EARTH

1 In the beginning

In the first 100 million years of the Solar System, rocks collided and collected to form a hot ball of rock and metal.

2 The first oceans

As Earth started to cool, water condensed in the atmosphere, raining down on the ground and forming the oceans.

3 Snowball Earth

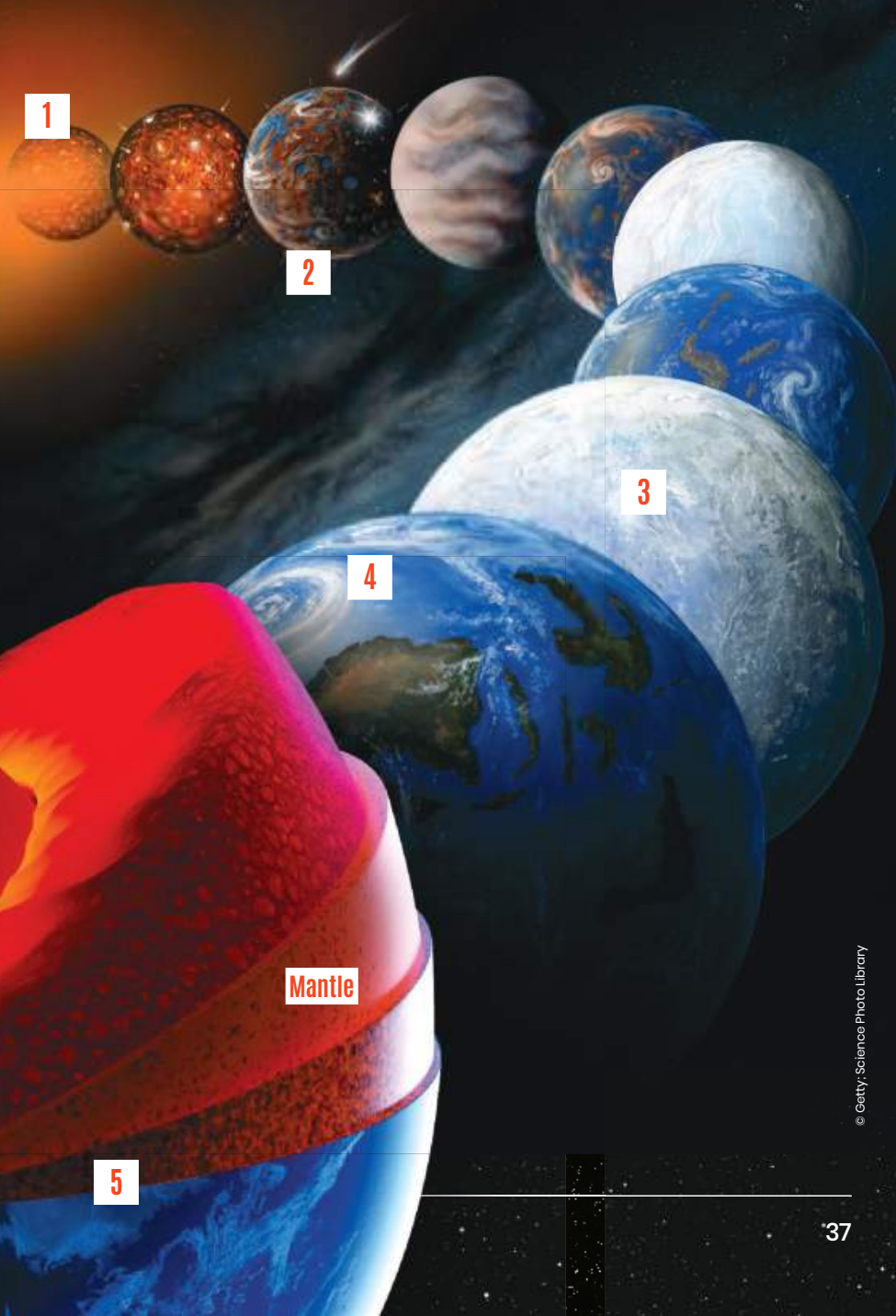
As the continents shifted and life began to evolve, the atmosphere altered. Earth swung between periods of extreme heat and frigid cold.

4 The rise of the supercontinents

The tectonic plates continued to move relentlessly, shuffling Earth's continents into different configurations.

5 Modern Earth

Even today, the continents and the atmosphere are evolving around us.



Inner core

Mantle

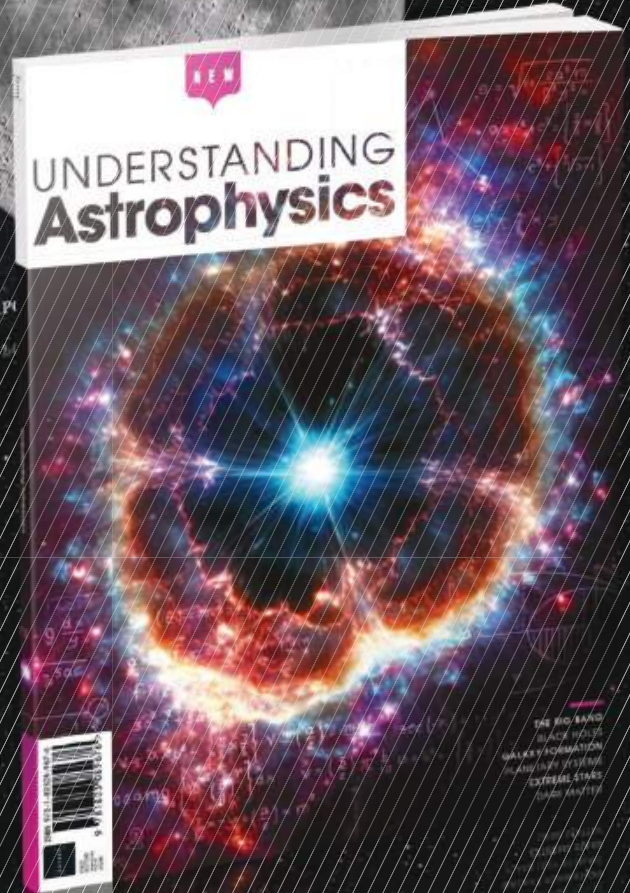
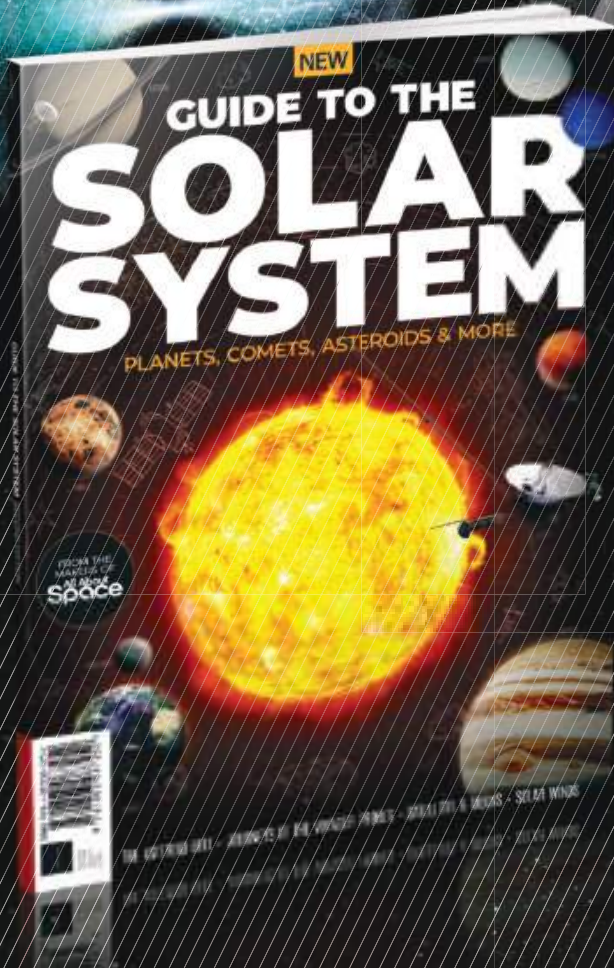
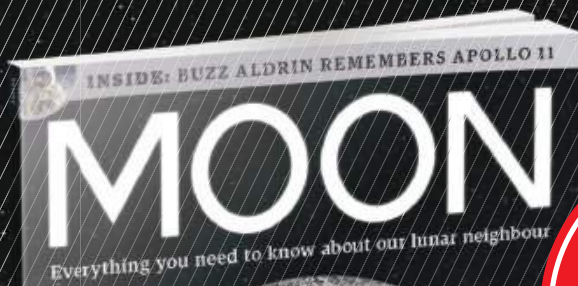
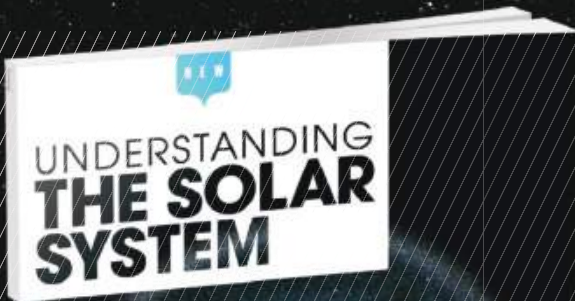
Outer core

5

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FOCUS ON

NASA'S NEW HORIZONS WILL INVESTIGATE URANUS AND NEPTUNE, AND YOU CAN HELP

By taking part, you could help solve the mystery of Uranus' missing heat

Reported by Tariq Malik

NASA's New Horizons spacecraft is embarking on an observing campaign of the ice giants, and scientists need your help. Although New Horizons is now far beyond both Uranus and Neptune, throughout September it will be turning its Multispectral Visible Imaging Camera (MVIC) back to look at them from a vantage point more than 8 billion kilometres (5 billion miles) from Earth. In doing so, it will be seeing these worlds from the opposite direction to how we see them from Earth. To ensure wide coverage of the two planets from a variety of angles, New Horizons will be joined in this endeavour not only by the Hubble Space Telescope, but also by amateur astronomers all over the world, who are being asked to contribute observations throughout the month.

Of all the planets in our Solar System, Uranus and Neptune are the least understood. They've only been visited once before, by Voyager 2, and their sheer distances mean they can't be seen in great detail from Earth, so there's still lots to learn about them. New Horizons' primary science objective for these observations is to learn more about how the atmospheres of the two worlds absorb and emit heat energy, as well as how thermal energy is transported from the planets' cores to their outer atmospheres. Uranus in particular is odd in this regard because it appears to have hardly any heat flowing from its interior into space. Neptune, despite being a similar planet at first glance, radiates over two-and-a-half times more energy into space than Uranus does.

There are several possible explanations for why hardly any heat seeps out of Uranus. One is that an impact may have knocked Uranus onto its side billions of years ago, causing the planet's core to lose all its heat at once. Another is that some kind of layer deep

within Uranus' atmosphere blocks heat from escaping. New Horizons' observations intend to get us closer to an answer. "By combining the information New Horizons collects in space with data from telescopes on Earth, we can supplement and even strengthen our models to uncover the mysteries swirling in the atmospheres of Uranus and Neptune," Alan Stern, New Horizons' principal investigator from the Southwest Research Institute in Boulder, Colorado, said. "Even from amateur astronomy telescopes as small as 16 inches, these complementary observations can be extremely important."

Telescopes with apertures of 16 inches are technically considered quite large for amateur astronomers. With a telescope of this size, observers will be able to image and track activity in the atmospheres of both planets. This activity is driven by the flow of thermal energy, both from inside the planet and from the Sun, and comes in the form of huge, swirling storms that appear as bright spots in the atmosphere. The upcoming coverage from New Horizons, the Hubble Space Telescope and hundreds of amateur astronomers worldwide is planned to be the most complete survey of Uranus and Neptune ever.

Given the placement of Uranus and Neptune in our sky during September, New Horizons' observing campaign also comes at just the right time for amateur astronomers. Neptune is at opposition on 19 September, with Uranus following two months later on 13 November. Opposition occurs when a planet is directly opposite the Sun as seen from Earth, which means the planet is invariably at its best and brightest. Observers are encouraged to post their images with supporting information to social media using the hashtag #NHIceGiants, where the New Horizons team will collate them all and select the best for inclusion in the study.

3

3 Solar Wind Around Pluto (SWAP)

This instrument measured the rate at which Pluto's atmosphere is being lost to space due to gusts of the solar wind.

2 Pluto Energetic Particle Spectrometer Science Investigation (PEPSSI)

PEPSSI measured the composition and density of gas leaking from Pluto's atmosphere.

1 Radio Science Experiment (REX)

Built into the radio antenna, REX used its radar to measure the temperature and pressure of Pluto's atmosphere.

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4 Long-Range Reconnaissance Imager (LORRI)

This telescopic camera was used to image Pluto from long distances in the months ahead of the flyby.

5 Star trackers

The star trackers are required for navigation purposes, capable of using the positions of the stars to determine the spacecraft's position, orientation and trajectory.

6 Venetia Burney Student Dust Counter (VSDC)

Built by students at the University of Colorado, Boulder, this instrument was designed to count the abundance of dust particles in the outer Solar System.

9 Radioisotope thermoelectric generator (RTG)

A nuclear power source to keep the spacecraft powered up.

8 Alice

Alice studied Pluto's atmosphere and looked for an atmosphere around its moon Charon.

7 Ralph

Ralph mapped the temperature and composition of Pluto's surface.



10 IMPOSSIBLE COSMIC PHENOMENA

We know a lot about space, but there's more we can't explain... including these ten things that appear to defy science

Written by Shanna Freeman

1 AN UNEXPLAINED CLUMP OF DARK MATTER

Dark matter sounds ominous, but scientists believe that it comprises more than 80 per cent of all matter in the universe. It can't be seen or directly detected because it doesn't emit light or any type of radiation, but we've inferred its presence from how it affects objects that we can see. Typically, galaxies are surrounded by clouds of dark matter. Yet astronomers have found that a clump of dark matter located about 2.4 billion light years away appears to be all alone – no galaxies attached. Nearby galaxies collided and are now part of a merging galaxy cluster called Abell 520, but for some reason they left their dark matter behind. The clump was first detected in 2007 by the Canadian Cluster Comparison Project (CCCP). The CCCP's findings were reviewed by the Japanese Subaru telescope. Scientists were so puzzled that it was also part of a 2012 investigation by the Hubble Space Telescope, which confirmed that this

clump of dark matter has been abandoned. However, additional research by a team at Ohio University found the ratio of dark to normal matter in the cluster to be normal. Clearly, further observations are needed to reveal the exact composition of Abell 520 and figure out how it formed.



2 THE MYSTERY SPEED BOOST

There's a curious anomaly that happens when space probes conduct flybys over certain moons and planets in our Solar System: their speeds change slightly beyond what scientists expect. For example, when the Rosetta probe flew by Earth in 2005, it gained about 1.82 millimetres (0.07 inches) per second of speed, while in 1998 the Near Earth Asteroid Rendezvous (NEAR) spacecraft increased its velocity by 13 millimetres (0.5 inches) per second after an Earth flyby. Spacecraft use these flybys as a gravity assist, allowing them to gain momentum from the motion of a moon or planet in order to save fuel and reach their ultimate destinations faster. Rosetta, which also had help from the gravity of other celestial bodies, was on its way to observe comet 67P/Churyumov-Gerasimenko.

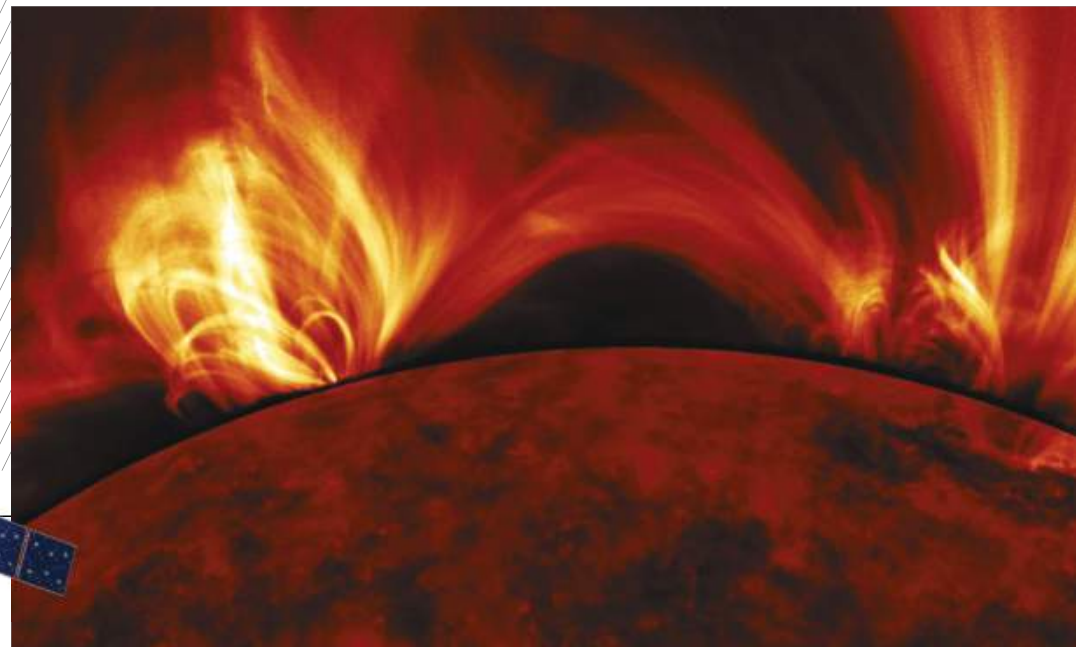
They're supposed to speed up, but the point is that they're doing so by more than the expected amount. The numbers just don't add up. Although a discrepancy of millimetres per second doesn't seem to make much difference and hasn't caused any problems, scientists want to figure out what's causing it. We know that the flyby anomaly has occurred elsewhere, but we're best able to measure it when it happens around Earth because of our monitoring stations. There are many hypotheses in the mix, including a halo of dark matter trapped by Earth's gravity or the influence of magnetic fields, tides or solar radiation.



3

THE STAR THAT SPINS TOO FAST

Pulsars are rotating neutron stars that emit electromagnetic radiation, and while most of them make a few rotations per second, some are speedsters. Called millisecond pulsars, they can rotate at a rate of between one and ten milliseconds. Sometimes they're called recycled pulsars because it's thought that these stars originally had a slower rotation, but were sped up when they accreted matter from a companion star, recycling it. Until the discovery of the pulsar PSR J1748-2446ad, astronomers believed that stars couldn't spin faster than 700 rotations per second, or 700 Hertz. In 2005, astronomer Jason



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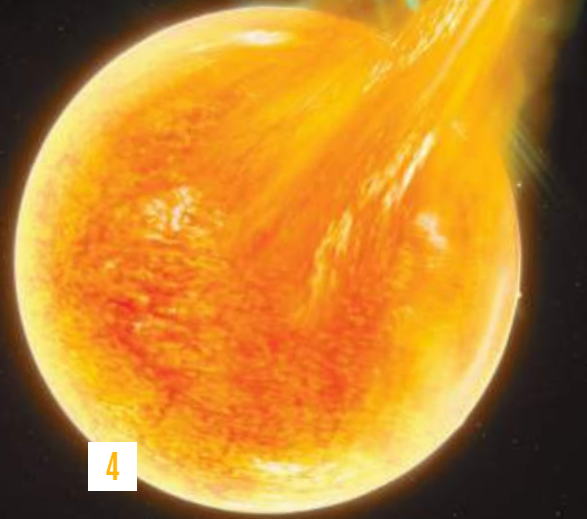
Hessels clocked this star spinning at 716 Hertz. Although theoretically a pulsar could spin at up to 3,000 rotations per second before breaking apart, previously we thought that their speeds were limited by the emission of gravitational waves. So either PSR J1748-2446ad emits many, very strong gravitational waves, or the models are wrong. Figuring out the star's size would be useful in solving this puzzle, because it's believed that it can't be over 16 kilometres (9.9 miles) across – any larger and it would come apart at that speed. Although we believe it's got a mass about twice that of our Sun's, measuring its radius has proven difficult because it's orbited by a large star that blocks its light much of the time.

1 In a tango
A massive supergiant star and a main sequence star similar to our Sun orbit each other in a binary system.

2 Running out of fuel
The massive star exhausts its fuel, exploding in a supernova and leaving behind a neutron star. For millions of years that neutron star behaves as a radio pulsar and spins at an incredible rate. It eventually slows down, turning itself off and cooling down.

3 A great survivor
After billions of years, if the binary survived the explosion, the smaller star evolves and expands into a red giant. Material from that star spills into a disc around the neutron star and onto its surface. The neutron star then spins much more rapidly and spits out X-rays.

4 Super-spinning pulsar
The neutron star is now spinning rapidly, emerging as a millisecond radio pulsar.



4

A LAYER OF THE SUN IS TOO HOT

For 80 years scientists have tried to work out why the Sun's corona – the layer of plasma around it – is at least 1 million degrees Celsius (1.8 million degrees Fahrenheit) hotter than the Sun's surface. The core of the Sun is around 16 million degrees Celsius (28.8 million degrees Fahrenheit), and the temperature decreases the further you get from the centre. The photosphere is an estimated 6,000 degrees Celsius (10,832 degrees Fahrenheit). According to the second law of thermodynamics, the corona can't be heated up through the Sun's layers from the core. But that

energy has to reach the atmosphere somehow. Despite its intense heat, the corona isn't very dense, so it doesn't need much energy. Scientists have several theories as to how this happens, but two main ideas have surfaced that are related to activities taking place on the Sun's surface. One is that the corona gets energy from snapping loops in the magnetic field, and the other is that the heating comes from magneto-acoustic waves carrying energy from below the surface. Recent observations suggest it's the latter, but figuring out the relationship between the corona and these waves is proving difficult.

5

AN ALIEN WORLD THAT SHOULD BE SWALLOWED BY ITS STAR

Discoveries of exoplanets have been coming thick and fast thanks to NASA's Kepler and Transiting Exoplanet Survey Satellite (TESS). Even more interesting is the discovery of Earth-like planets – ones that are about the size of Earth and with a similar composition. Kepler-78 b, tightly orbiting its star less than 1.6 million kilometres (1 million miles) away in a speedy 8.5 hours, somewhat fits the bill of an Earth-like planet. It's about 20 per cent larger than Earth and is believed to also have an iron core and a rocky surface – although the close orbit means that the surface is at least 2,000 degrees hotter than our planet's. But Kepler-78 b certainly didn't form the same way that Earth did. In fact, we have no idea

how it formed. It couldn't have formed in place, because the younger and larger star would've encompassed its current orbit. Nor could Kepler-78 b have once had a larger orbit and then moved in closer towards the star, because by this time it should've gone all the way in. All we do know is that Kepler-78 b will eventually be swallowed by its star, and sooner rather than later.

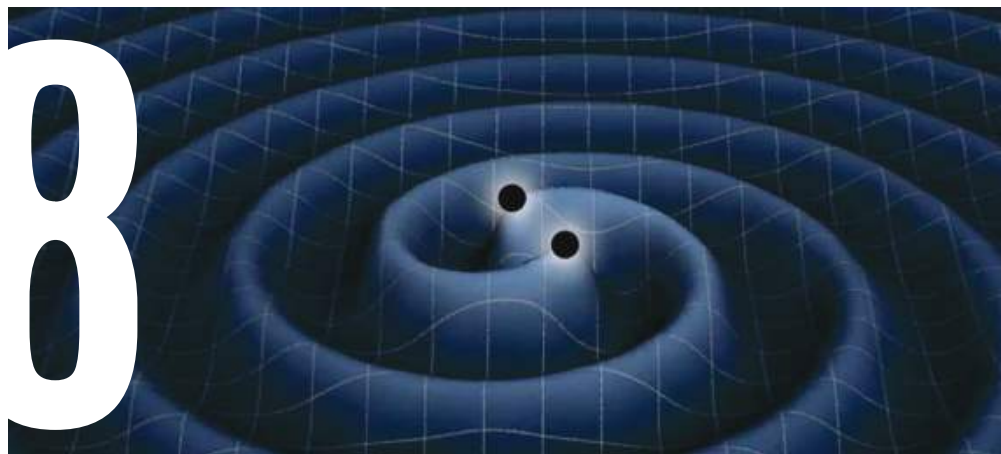
6 THE GALAXY THAT'S TOO NEAT AND TIDY

BX442 is the most distant known grand-design spiral galaxy in the universe and is also believed to be a very old galaxy, forming about 3 billion years after the Big Bang took place. Typically, galaxies of this age are very messy looking – they're asymmetrical, lumpy and very irregular. BX442, though, is beautifully symmetrical and neat – closer in appearance to more recently formed galaxies than ancient ones. The Hubble Space Telescope first spotted this galaxy in 2012, and scientists had to double-check that Hubble had really found a single grand-design spiral galaxy and not two galaxies that happened to be imaged while aligned. We thought that galaxies like this couldn't exist so early in the history of our universe, but BX442 is there rotating in its perfect glory all the same. One theory is that gravitational interactions with its companion dwarf galaxy have somehow influenced BX442's spiral structure, but further research will have to reveal what's going on to keep the galaxy looking so young.



7 THE STAR THAT SHOULDN'T EXIST

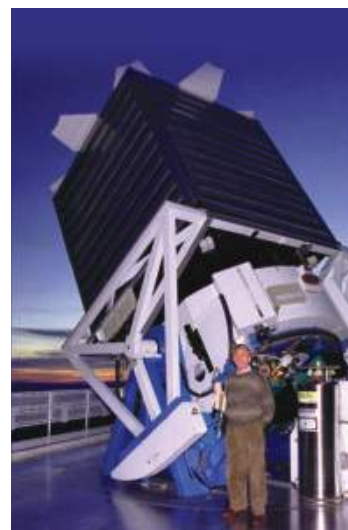
At first, SDSS J102915+172927, also known as Caffau's star, doesn't seem like much of a standout. However, the Sloan Digital Sky Survey (SDSS) noted that the star had potential to be unusual due to its spectrum, which indicates the mix of elements within the star. It's located in Leo and has a very low mass of just 0.8 solar masses. Caffau's star is slightly hotter than our Sun, and it's believed to be one of the oldest stars in the galaxy at 13 billion years of age – about 8.5 billion years older than the Sun. Yet this star resides in what is called the 'forbidden zone' of the theory of star formation, meaning that according to what we know, it shouldn't exist at all. That's because Caffau's star comprises almost entirely hydrogen and helium, with only minute amounts of metals – elements heavier than helium. It's long been believed that all stars contain certain elements necessary for formation, and a very old Sun-like star like Caffau's star should have significant amounts of oxygen and carbon. But since it doesn't, our current recipe for star formation must be faulty – or maybe there's more than one way to make a star.



8 THE GRAVITATIONAL WAVES THAT SPEED STARS UP

Gravitational waves are a phenomenon predicted by Einstein's theories that transport energy as gravitational radiation in the form of ripples that produce curvatures in the space-time continuum. In 2012, some astronomers discovered gravitational waves via changes in the light emitted by a white dwarf binary system called SDSS J065133.338+284423.37, or J065133 for short. These stars are located about 3,000 light years away and orbit each other at a distance that's one-third the distance between Earth and the Moon.

Their close proximity means that they complete an orbit in less than 13 minutes, eclipsing each other every six minutes. The gravitational waves that they generate carry energy away, speeding up their orbits and causing the stars to move closer together. Because the orbital period is so short and regular, scientists have already noticed that it's shrinking. In about 2 million years, the stars in J065133 are predicted to merge. Meanwhile, we can learn more about gravitational waves by observing this system.



© NASA; Dan Long, Apache Point Observatory; Keck Observatory; Institute for Astronomy

9 TWO STARS THAT DON'T BELONG TOGETHER

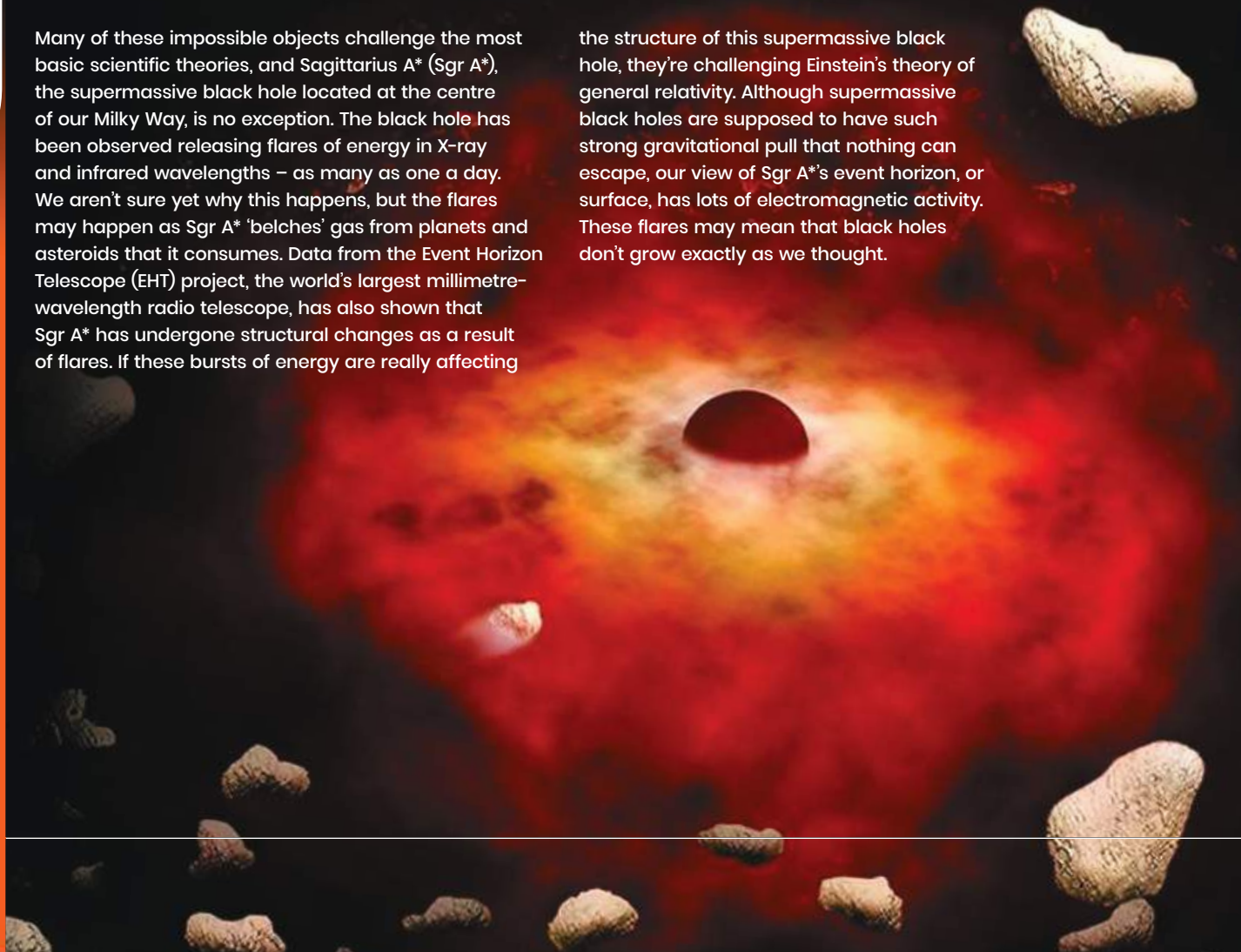
This binary system is a real odd couple. Discovered in 2007, it contains a neutron star orbited by a white dwarf. The neutron star, PSR J0348+0432, is a pulsar that spins about 25 times per second. It's both very small and very massive – one of the most massive neutron stars ever discovered. Although it's just an estimated 20 kilometres (12 miles) in diameter, this pulsar is twice as massive as the Sun and its gravity is more than 300 billion times that of Earth's. It's unusual enough by itself, but then there's the white dwarf in orbit around it – a very light star that is about a million times too faint to be seen with the naked eye. Its mass is less than one-fifth of the Sun's, creating a radically extreme mass ratio of 1 to 11.7. It also has an unusually short orbital period of just two hours and 27 minutes, and the stars are just 830,000 kilometres (515,738 miles) apart from each other. Theoretically, this binary system of extremes shouldn't work. They shouldn't exist together, but somehow they do.



10 A BLACK HOLE THAT CHALLENGES EINSTEIN

Many of these impossible objects challenge the most basic scientific theories, and Sagittarius A* (Sgr A*), the supermassive black hole located at the centre of our Milky Way, is no exception. The black hole has been observed releasing flares of energy in X-ray and infrared wavelengths – as many as one a day. We aren't sure yet why this happens, but the flares may happen as Sgr A* 'belches' gas from planets and asteroids that it consumes. Data from the Event Horizon Telescope (EHT) project, the world's largest millimetre-wavelength radio telescope, has also shown that Sgr A* has undergone structural changes as a result of flares. If these bursts of energy are really affecting

the structure of this supermassive black hole, they're challenging Einstein's theory of general relativity. Although supermassive black holes are supposed to have such strong gravitational pull that nothing can escape, our view of Sgr A*'s event horizon, or surface, has lots of electromagnetic activity. These flares may mean that black holes don't grow exactly as we thought.



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FOCUS ON

THE ARTEMIS IV CREW WILL BE THE FIRST TO USE NASA'S MOON-ORBITING GATEWAY

The crew will include one European astronaut

Reported by Sharmila Kuthunur

The first mission to make use of NASA's Gateway space station will be Artemis IV, now scheduled to launch in 2028.

NASA and its international partners see Gateway as a key platform to support the agency's Artemis Moon program and to build the technology required for future deep-space missions. Although the first elements of the small space station are expected to launch before the Artemis III mission lifts off in 2025 or 2026, NASA previously said that those astronauts will not use Gateway to "make that mission have a higher probability of success."

Instead, the astronauts of the Artemis IV mission, who will attempt the program's second landing on the Moon in 2028, will be the first ones to live and work in the small lunar outpost. The first two elements of the orbiting space station – one of which is the Habitable and Logistics Outpost (HALO), where astronauts will live and carry out research – are scheduled to be integrated on Earth and launched together in late 2025. By the time the first crewed mission arrives at the small space station, NASA plans to add a second habitable module.

The consequent Artemis V mission, currently scheduled for 2029, will carry a refueller for the lunar outpost. The European Space Agency (ESA), in partnership with Japan, will be providing the refuelling module as well as the second habitat module. In

A LUNAR GATEWAY

1 Orion spacecraft

It's this module that brings astronauts from Earth and returns them home at the end of a mission.

2 External robotics

The Canadian Space Agency will provide an external robotic arm, similar to the one that's on the ISS.

return, European astronauts will receive three flight opportunities on board Artemis missions to get to and work on the lunar outpost and touch down on the Moon. Two of those missions will be Artemis IV and V, with the third one yet to be announced.

While Gateway will serve as a compact home for astronauts, it's being built so that it can operate autonomously without a crew for up to three years between missions. That autonomy is quite different from the International Space Station (ISS), which has been continuously crew-occupied for over 20 years and is scheduled to retire in 2030. "It's not a stretch to say

that Gateway is very much a part of the ISS legacy," said Stephanie Dudley, the mission integration and utilisation manager for Gateway.

The crew size on the two space stations will be different, too. While the ISS has hosted a maximum of 13 astronauts at one time, Gateway, which is a fifth of the size of the ISS by volume, caps out at four crew members for a maximum of 90 days. Dudley emphasised that science experiments performed on Gateway will leverage the station's unique position around the Moon and will provide results even without a crew being present. So far, the initial research experiments announced last year fit this criteria. Taking advantage of Gateway's orbit far away from Earth's protective magnetic field, three instruments will study risks due to radiation from the Sun and from cosmic rays. Scientists hope this knowledge can help inform future long-term missions to the Moon and Mars.

3 SpaceX rocket

The core elements of HALO and PPE will be launched using SpaceX's Falcon Heavy rocket.

4 ESPRIT

The European System Providing Refuelling, Infrastructure and Telecommunications is being provided by the European Space Agency.

5 Logistics module

Various companies, starting with SpaceX, will provide robotic craft to resupply the station from Earth.

6 Power and Propulsion Element (PPE)

The PPE, built by Maxar Technologies, will be a 60-kilowatt solar-powered module providing electricity, communications and other services.

7 Habitation and Logistics Outpost (HALO)

HALO, under development by Northrop Grumman, will provide crew quarters for astronauts en route to the lunar surface.

8 Human Landing System

The shuttlecraft to take astronauts down to the Moon's surface will be based on SpaceX's Starship vehicle.



FOCUS ON

100-YEAR 'MEGASTORMS' ON SATURN SHOWER THE PLANET IN AMMONIA RAIN

The atmospheric turbulence of the gas giant put Earth's

Reported by Robert Lea

Scientists have discovered that Saturn experiences long-lasting megastorms that persist for centuries and churn up its deep atmosphere. Saturn had previously been considered somewhat calmer than its fellow gas giant Jupiter, which has been home to a huge storm called the Great Red Spot for hundreds of years.

The megastorms of Saturn, thought to occur between every 20 and 30 years, are similar to hurricanes on Earth but are much larger. Whereas Earth's hurricanes get energy from our planet's oceans, the mechanism driving megastorms in the hydrogen and helium-rich atmosphere of Saturn is somewhat mysterious. But astronomers from the University of California, Berkeley, and the University of Michigan have learned more about these storms on Saturn by studying disruptions in the distribution of ammonia gas in the planet's deep atmosphere. "Understanding the mechanisms of the largest storms in the Solar System puts the theory of hurricanes into a broader cosmic context, challenging our current knowledge and pushing the boundaries of terrestrial meteorology," University of Michigan assistant professor Cheng Li said.

Li and the team detected this disruption by looking at radio emissions from ammonia in Saturn's atmosphere using the Karl G. Jansky Very Large Array (VLA) in New Mexico. Though Saturn appears to have a mostly uniform colour in visible light, its distinctive banding and the differences between atmospheric layers at varying altitudes are more evident when seen in radio waves. That's because radio observations can peer deeper into planets' atmospheres than optical telescopes, allowing astronomers to better understand the chemical and physical processes that lead to cloud formation and the transfer of heat. "At radio wavelengths, we probe below the visible cloud layers on giant planets," University of California, Berkeley, astronomer Imke de Pater said. "Since chemical reactions and dynamics will alter the composition of a planet's atmosphere, observations below these cloud

layers are required to constrain the planet's true atmospheric composition, a key parameter for planet-formation models."

The team found something surprising in radio emissions emanating from within the atmosphere of Saturn in the form of anomalies in ammonia concentrations. They were able to connect these anomalies to prior megastorms that raged through the gas giant's northern hemisphere. The concentration of ammonia was lower in the middle latitudes of Saturn, suggesting a higher ammonia ice-cloud layer. Around 100 to 200 kilometres (160 to 320 miles) below this, however, concentrations of ammonia increased. The team thinks that this enrichment is the result of ammonia being transported from the upper layers of the atmosphere to the lower layers in the form of ammonia rain. This effect is the result of megastorms and can last for hundreds of years.

✓ An artist's impression of Saturn



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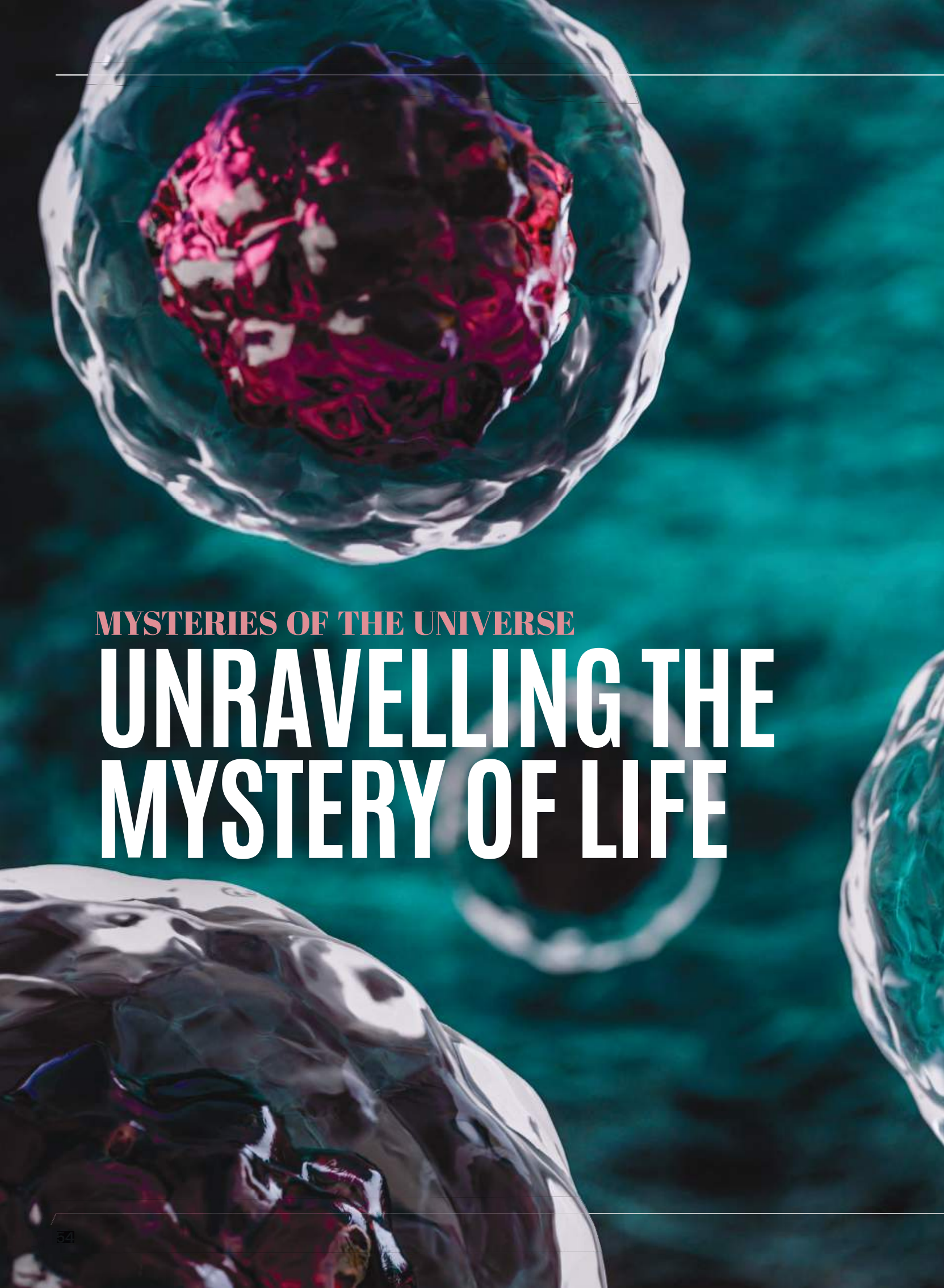
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MYSTERIES OF THE UNIVERSE

UNRAVELLING THE MYSTERY OF LIFE

Scientists have begun taking a new approach to discovering the origin of life and are already bridging gaps in our knowledge

Reported by David Crookes

We know for certain that life exists. What we don't know is exactly how life originated on Earth and whether life exists elsewhere. Yet knowing how basic biological systems came into being would help scientists work out how our world became teeming with plants, insects and animals. It would also assist enormously in the search for extraterrestrial life. "Life is probably the most complex naturally occurring phenomenon in the universe, and the gap between living cells and non-living chemistry is vast," explains Aaron Goldman, an associate professor of biology at Oberlin College in Ohio. "It's pretty amazing that life exists at all and fascinating to think about how life, even the simplest life, could have first originated on the early Earth."

Goldman has made it his mission to work out the best way of learning what life actually is and how it works at the most fundamental level. Such endeavours take into account that life, when it emerged at least 3.8 billion years ago, would have been very different to how it presents itself today. The atmosphere would have been rich in methane and lacking oxygen, with life restricted to microbes lacking specialised cells. "While we haven't figured out exactly how life originated, the field has developed some pretty good models about what kinds of environments and chemical reactions could have produced precursors to the kinds of biomolecules that are used by life today," Goldman continues. "At the same time, techniques from evolutionary and

➤ Shallow-sea alkaline hydrothermal vents could have facilitated prebiotic chemistry on the early Earth and on other watery worlds

⌚ The bottom-up approach starts with the formation of the Earth itself



It seems simple – so much so that it's a surprise it hasn't been raised before – but it's also a strategy that has some heavy backing, not least from NASA, which believes such research could unlock the mystery of how life not only formed on Earth, but also on other planets. If there is a better understanding of how life can form, there's a chance it could unearth greater diversity. Our concept of alien life may be turned on its head by widening the number of markers for life to watch out for. "As we search for extraterrestrial life, our understanding of what we are looking for is both informed by and limited by our knowledge of life on Earth," Goldman says. "We only have one example of life, and the markers we look for as signs of life on other planets are extrapolations based on which features of life on Earth we expect might be general to life in the universe. If we can discover how the most foundational characteristics of life on Earth first evolved and what the earliest life forms might have been like, especially those that lacked some of the now-universal characteristics of life today, then this would allow us to understand life in more general terms and possibly expand our search for life elsewhere."

But how would it work? To understand, it's worth looking a little deeper at the limitations of both approaches and at what they have been able to tell us thus far. The top-down approach has been able to identify the environments in which life could form based on the genes still conserved in contemporary organisms. "Based on these experiments, several geochemical environments – clays, ices, minerals, hydrothermal vents – have emerged as potential settings for the origin of life,"

SEARCHING FOR LIFE BY NUMBERS

There are more than
5,000
exoplanets in our galaxy, but scientists think there could be trillions of them

There's an estimated
100 billion
galaxies in the universe, yet we have found zero worlds with life

It took
4.25 billion
years for technological life to emerge on Earth

Studies have suggested there's a
75%
probability of life elsewhere

ONE
telescope could help: the James Webb Space Telescope

SETI has
100
scientists on the lookout for life

computational biology are allowing us to reconstruct the earliest ancestors of very ancient genes and predict with some confidence what molecular functions they might have encoded, leading to a much better understanding of what some of the earliest organisms might have been like."

One of the decisions faced by scientists trying to decipher how life emerged is which method they should use. On the one hand, researchers can take a top-down approach. This looks at data from life today and works backwards, trying to work out how early life forms may have appeared in the past. On the other hand, researchers can take a bottom-up approach. This seeks to use laboratory experiments to simulate Earth's early environment, going back to around 4.28 to 3.77 billion years ago. "The bottom-up approach looks for the production of precursors to today's biomolecules," Goldman says. Both have shortcomings, however.

"When I was in graduate school, I read an article by the chemist Addy Pross, in which he defined bottom-up research as 'ahistorical,'" Goldman explains. "These kinds of laboratory experiments can tell us about how life could have emerged, but not how life did emerge. Top-down research is inherently historical. It uses ancient gene families that still exist in the genomes of organisms today in order to reconstruct what early life might have been like. Unfortunately, these kinds of evolutionary reconstructions can only see as far back in time as the most ancient genes that still have present descendants."

Such shortcomings bind researchers. Although they're both trying to reach the same end, the two approaches only allow scientists to go so far. That's proven mightily frustrating over the years, leaving questions insufficiently answered. But there could be another way, Goldman proposes. What if the top-down and bottom-up approaches were combined? "We have one approach that allows us to investigate the origin of life itself, but does not give us a historical account. We have another approach that can give us a historical account, but is unable to investigate stages at or following the origin of life," Goldman continues. "But if we can find ways to combine these two approaches, we can potentially begin to understand the origin of life as it actually did occur on the early Earth."



HOW OUR WORLD EVOLVED

Earth looks very different today than it did more than 3 billion years ago

1 Green oceans

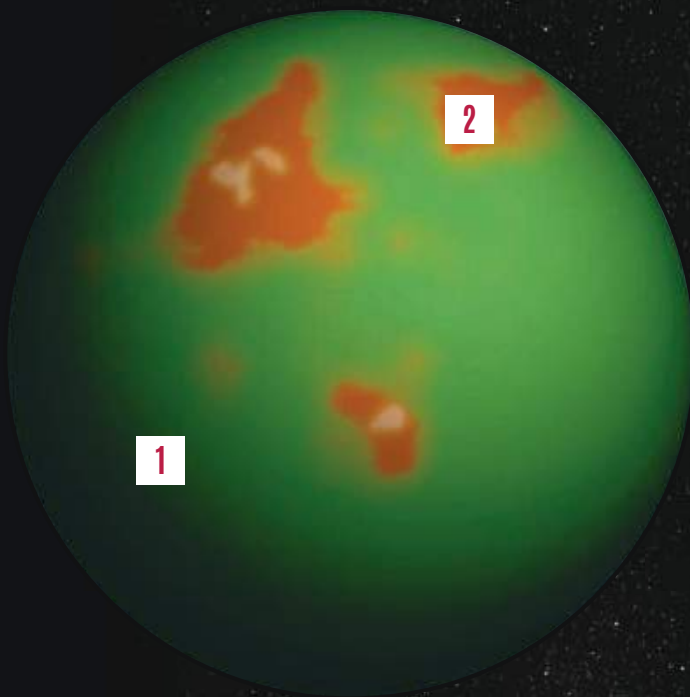
An abundance of iron ions in the water would have meant the oceans appeared green. It's also been suggested that Earth's primordial ocean could have covered almost the entire planet.

2 The proto-continents

No Americas, Asia, Africa, Antarctica, Australia or Europe: Earth's landmass was a world apart. The proto-continents were rich in magnesium, and plate tectonics may not have yet begun.

3 The world today

Earth is teeming with life, but we've drawn a blank in our search elsewhere. There may be microorganisms in subsurface ice or water on Mars, while Europa and Enceladus are potentially habitable.

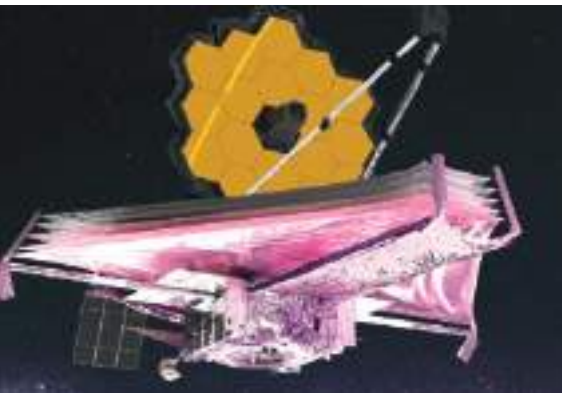


EARLY ARCHEAN



PRESENT DAY





Goldman says. “There’s no way to know which of these environments, if any, was the historical setting for the actual origin of life, but each can be studied as plausible routes towards a possible origin of life.”

The bottom-up approach allows scientists to consider prebiotic chemistry, working with materials that would have been present on the prebiotic Earth. “From this perspective, the oldest biological system that we can reconstruct is the process of translation, in which organisms use the genetic code to read genes from our DNA and produce proteins that then go on to perform molecular functions in the cell,” Goldman

says. “This system, including the genetic code and all of the relevant machinery, appears to have evolved before the time of the last universal common ancestor. Despite its age, even the translation system is very complicated, and a lot of evolution must have occurred between the origin of life and the most ancient version of the translation system that we can reconstruct with evolutionary methods.”

With a combination of the two, it’s possible to look more deeply into certain aspects of life, such as metabolic reactions. Indeed, it’s this specific area that Goldman has been studying, publishing the results in the *Proceedings of the National Academy of Scientists*. His article, ‘Electron Transport Chains as a Window into the Earliest Stages of Evolution’, was written with Laurie Barge, a research scientist in astrobiology at NASA’s Jet Propulsion Laboratory, and colleagues.

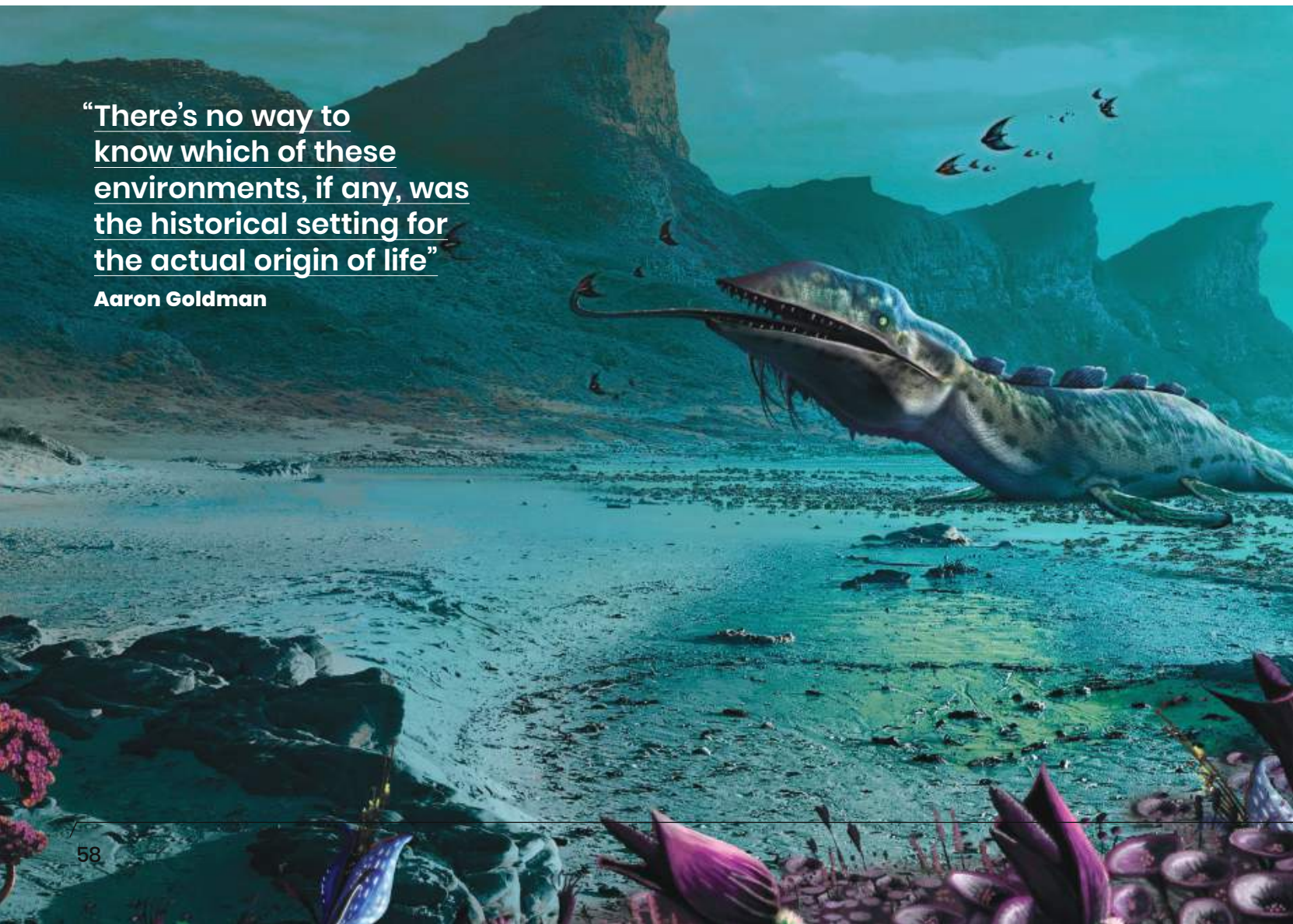
“Metabolic reactions offer a great opportunity to pair top-down and bottom-up research,” Goldman affirms, pointing to a type of metabolic system called electron transport chains, used from bacteria to humans to produce usable forms of chemical energy. “The enzymes

that facilitate metabolic reactions often have small catalysts within them, called ‘cofactors’, that other researchers have proposed may be vestiges of a proto-metabolism that predates the existence of enzymes. Some of these cofactors look like small versions of minerals that may have been important geochemical catalysts during the origin of life. Others look like small pieces of early biomolecules that could have predated the kinds of protein-based enzymes life uses today.”

He says that top-down research has shown that electron transport chains were used in very early life forms, while bottom-up evidence suggests electron transport chain-like chemistry would have been facilitated by early Earth ocean water and minerals. “Because enzymes today are made of proteins that are encoded by genes, we can use top-down approaches to reconstruct what some of the most ancient versions of these enzymes might have been like,” he explains. “At the same time, we can replace the enzymes and their small catalytic cofactors with the minerals and early biomolecules that may have preceded them in early evolution. In doing so, we can

“There’s no way to know which of these environments, if any, was the historical setting for the actual origin of life”

Aaron Goldman



WHAT'S THE BEST WAY OF DISCOVERING THE ORIGINS OF LIFE?

Two main approaches can combine to create a third way

Top-down approach

This traces back life to earlier days based on the information we have about life today. But this doesn't take into account any genes that have not been conserved. The research can't probe the stages that occurred during or after the origin of life.

Bottom-up approach

This uses laboratory experiments to simulate early Earth environments to see how life could have formed from raw materials that existed in our prebiotic world. But it only deals in possibilities and can't pin down the exact way life formed.

Combined approach

By pairing up both approaches, there's a chance scientists can hit upon a common set of conditions somewhere up and down the line. This has already been demonstrated with the study of electron transport chains.



▲ It's common to use computers to simulate the conditions of early Earth to predict how life could have emerged there

▶ The James Webb Space Telescope will aid the search for life. Knowing more about how life originated on Earth will help enormously in knowing what to look for

◀ There are lots of weird and wonderful creatures on Earth, but we don't know for certain if life would originate on other worlds in the exact same way

bring top-down and bottom-up approaches together to look deeper into evolutionary history than the genetic analysis allows us to do on its own."

The consequences of the combined approach are far-reaching. In fact, just looking at electron transport chains gives us more clues about how life came to be because it suggests the processes involved were present before life emerged. By establishing a link between a protocellular stage and early evolutionary history, there's a lot of scope for groundbreaking work, and it's a path NASA is keen to follow. "NASA defines astrobiology broadly, with the goal of understanding the past, present and future of life in the universe," Goldman says. "It has been a major supporter of research on the origin and early evolution of life. In 2016 it co-organised an Ideas Lab along with the National Science Foundation, aimed at planning and then funding potentially transformative research to address the origin and early evolution of the modern, two-polymer life system. Our team first coalesced around one of these Ideas Lab projects, and we have been working together ever since."

It's certainly clear a lot more work needs to be done – nobody is claiming to be anywhere near cracking the mystery of life's origins – but the future of such research can confidently continue to move forward.

It will require a multidisciplinary approach, with techniques from chemistry, biology, geology and computational modelling proving crucial. But it's a task being tackled with relish. "For a long time, the field of the origin of life seemed to operate under the assumption that what we needed was one really brilliant idea and the problem would be solved. More than half a century of research has demonstrated that the question is much more complicated than that," Goldman says. "The process that led to the emergence of life was probably complex, with multiple stages in different environments. I think the future of the field lies in recognising this complexity and fostering a culture of collaboration, especially between research groups that use different methods and areas of expertise. Like in any scientific pursuit, progress will come through meticulous and often incremental work. Ultimately, I have confidence that our understanding of the origin of life will be dramatically improved through efforts like this."

David Crookes

Science and technology journalist

David has been reporting on space, science and technology for many years, has contributed to many books and is a producer for BBC Radio 5 Live.



FOCUS ON

A SETTLEMENT COULD BE STARTED ON MARS WITH JUST 22 PEOPLE

Using computer simulations, scientists determined the personality types best suited for stays of up to 28 years on the Red Planet

Reported by Tariq Malik

New research suggests that a settlement on Mars could get up and running with far fewer settlers than previously predicted. The study also looked at what personality types are best adapted to long-term stays on the Red Planet. The research, conducted by scientists from George Mason University in Virginia and other institutions, looked at the challenges that would face Mars settlers as they build and maintain a self-sustaining human presence. The research comes as space agencies across the globe begin planning future long-stay space missions on the Moon and eventually on the Red Planet.

As the study has it, under two dozen people are needed to start a future Mars settlement. "From our multiple simulations and scenarios, we found that an initial population of 22 was the minimum required to maintain a viable settlement size over the long run," the authors wrote in a paper detailing their findings, which has not yet been peer-reviewed, published on the research repository site arXiv. "We find that the minimum number of people with all personality types that can lead to a sustainable settlement is in the tens and not hundreds."

To answer these questions and better determine the behavioural and psychological interactions of future Martian settlers, the team employed a computer modelling approach called Agent-Based Modelling (ABM). ABMs are commonly used

to study the interactions between people, things and places over time. The researchers also considered data regarding groups of humans in other high-stress remote situations, including aboard the International Space Station (ISS). This allowed them to test the minimum number of people needed to keep a Mars outpost running, sometimes for as long as almost three decades. The model used by the team assumes that the Mars settlement has already been constructed and that food, air and water are being produced in-situ on the Red Planet. That means that the simulated Martian base doesn't require start-up time.

The ABM settlement also has a nuclear generator established that has a steady source of electricity for a minimum of seven years. The purpose of this simulated settlement is to mine minerals from the Red Planet to be sent back to Earth. Running the test for 28 years five times over, the outpost population sizes varied from 10 to 170 to find the stable population size.

In addition to finding that a base could operate over long periods with just 22 people, the team determined that the settlement could survive if its population dropped as low as ten settlers, but only if it was built back up within 1.5 years – the time the simulation set between supply missions from Earth. The team went beyond this, also testing what type of person seems to be best suited to long stays on Mars. The simulations used by the team allowed them to account for the interactions between settlers by considering four basic personality types based on resilience and coping ability: agreeable, sociable, reactive and neurotic. In the models, Red Planet settlements started with an equal number of these four personality types. In all the tests, the researchers pointed out that the agreeable personality types were the only Mars settlers to last the duration of every single run.

Landing craft

We could send habitation modules to Mars with each new crew, eventually building up to the first settlement.

Longer days

The length of a Martian day, or sol, is 24 hours and 39 minutes. Astronauts will need special Mars watches that factor in this extra 39 minutes.

A self-supporting colony

Being so far from Earth, Martian explorers will have to be able to support themselves. An inflatable greenhouse could be put up to grow crops, although nobody knows how well plants will grow in the Martian dirt.

Looking for life

One of the main scientific goals when going to Mars will be to answer questions about life on the Red Planet.

Better than robots

What rovers have accomplished in years on Mars could have been accomplished by a team of astronauts in less time.

Underground water

Water ice lies just a few metres beneath the surface of Mars down to at least its mid-latitudes, and should be easily accessible.

PLANETS

How do you study the core of a planet?

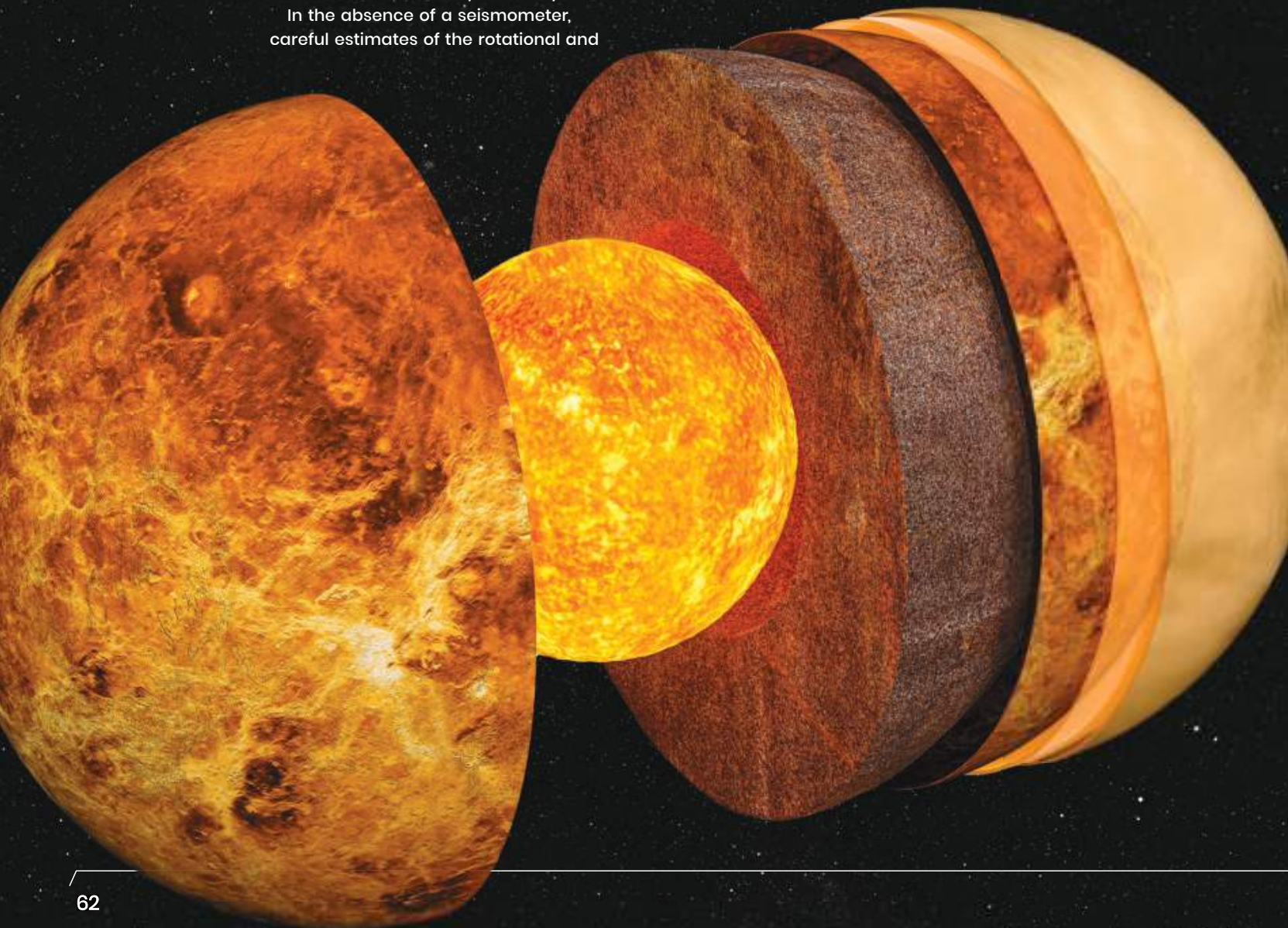
Planetary cores, dominated by iron in terrestrial planets, can't be directly sampled, but geophysics-based methods provide tools to probe the cores of planets and moons. On Earth, seismic waves were used to measure the core's radius. The now-defunct InSight mission used seismic shear waves reflected from the surface of the core to estimate Mars' core radius. These methods require a lander which is equipped with a sensitive seismometer and suitable seismic sources – in this case marsquakes. Similar techniques have been used to measure the small lunar core, where both moonquakes and surface impacts were detected. A future seismic mission to the Saturnian moon Titan is planned by NASA.

In the absence of a seismometer, careful estimates of the rotational and

gravitational properties of a planet, like those made for Mercury by MESSENGER or for Mars by orbiters and the InSight lander, can be used to infer properties of the core. Recent observations of vibrations in Saturn's rings have been used with gravitational measurements to learn about the properties of its huge ice-rock core. Finally, examination of planetary magnetic fields provides important information about the temperature and heat flow inside cores of some planets within our Solar System.



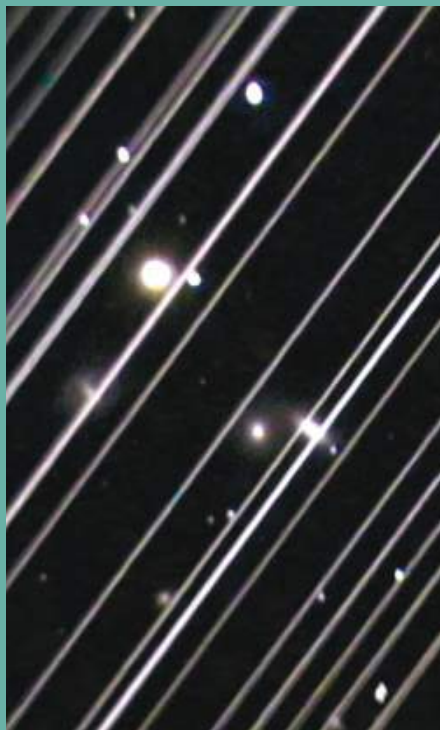
Dr Jessica Irving, senior lecturer at the School of Earth Sciences, University of Bristol



< Different methods and missions have informed us about planetary cores

> Starlink satellites are affecting the views around the world

✓ The rover is expected to launch in 2028



ASTRONOMY

If low-Earth-orbit satellites are problematic, could they just be placed higher?

Actually, that would be worse. It's a little complicated because you could think that maybe a lower orbit satellite would be brighter because it's closer, which is true, but the trick is that it moves faster in a lower orbit because it has to not fall out of the sky. That means that when you are taking a picture it will move out of the way faster and the pixels won't linger long enough to make as bright of a streak in the image, which is better.

I was personally disappointed that OneWeb decided to keep its satellites at a higher altitude, whereas SpaceX has been more willing to keep its satellites at lower altitudes. But space debris will become an even bigger problem at these lower altitudes as the lower the orbit, the more crowded it gets.

Dr Meredith Rawls, stellar astronomer and software developer working as a research scientist with the Vera C. Rubin Observatory Legacy Survey of Space and Time (LSST) group at the University of Washington



SPACE EXPLORATION

How will the Rosalind Franklin rover's Panoramic Camera work?

The special thing about PanCam is that we have a pair of good-resolution wide-angle cameras, but each has a filter wheel on the front of it to study the surface at 11 specific colours and wavelengths. They're specifically designed to look for water-bearing minerals, which should help us track down interesting targets for drilling. We can also do some atmospheric science with them, such as measuring the amount of water vapour in the atmosphere by looking at the sky and the way it affects certain wavelengths of sunlight.

The wide-angle cameras can give us very good stereo images for reconstructing the surface in 3D because they're placed 50 centimetres (19.7 inches) apart – much wider than human eyes. They're supplemented by a high-resolution camera that has a narrower field of view but a sharper image. Using that, we can add detailed texture to a 3D model of the surface near the rover. It's that, along with the geological information, which helps us know where to do our drilling.

To make sure we get the most accurate colour in our images, we're looking at a calibration target so that we can take account of the different lighting conditions on Mars. Getting the shapes right is another challenge – the

temperature changes inevitably introduce expansions and contractions in different parts of the rover, including the optics. The solution is to use 'fiducial markers' – these are little spots on the rover whose positions we know and can accurately measure. They give us a scale of measurement, so if any distortions creep in we can calibrate them out.



Professor Andrew Coates, professor and deputy director at University College London's Mullard Space Science Laboratory



"The temperature changes inevitably introduce expansions and contractions in different parts of the rover, including the optics"



SOLAR SYSTEM

Why are lava tubes on the Moon so important?

My belief is that in the future you'll have to live on the Moon. There will be some settlements on the Moon – or as we call it 'Moon Village' – maybe by 2035 or around that time frame, so you will have to build some structures for people to live in, and it will take a tremendous amount of energy and resources to build something like that. But if you have a lava tube, you already have an environment that is shielded from radiation and many other things. You are getting an environment where you can already store stuff, you can live and work there.

Robots and humans will be working alongside each other on the Moon, and I believe that exploring lava tubes is very important for future settlements. From a scientific perspective it's a very interesting environment that has been left alone for billions of years. For billions of years there has been no sunlight; for billions of years there has been no lunar dust. The lava tubes have been shielded from all those externalities, which isn't the case here on Earth. This means it's a very good potential site for science and to learn more about the universe.



Pavlo Tanasyuk, founder and CEO of space start-up Spacebit

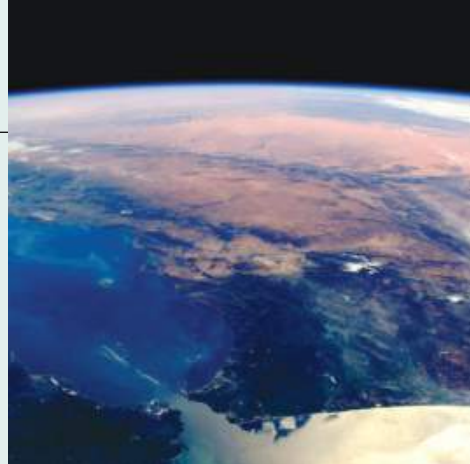
SPACE EXPLORATION

Are there any habits you pick up in space?

In terms of structure and routine, it's really helpful on the International Space Station that everything runs to a very clear structure and routine. And that's something I like to do in my life back here, because I think it helps. It really helps you just maintain that work-life balance. Exercise, for example, was something that was considered a luxury that happens when you get a few moments every day to go do something as opposed to being a scheduled routine activity that you need to set time aside for. On the International Space Station, everything is scheduled, with time allocated for everything, and it really just ensures that you get the basics of work, rest, nutrition and sleep.



Tim Peake became the European Space Agency's first British astronaut after launching into space on board a Soyuz rocket in December 2015



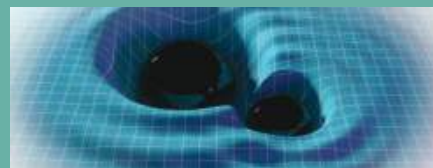
Ⓐ Routine is very important when living in space

Ⓢ Lava tubes could be the best places to build lunar bases

✓ Gravitational waves are like ripples through space-time

ASTROPHYSICS

What types of objects generate gravitational waves?



They're produced by pretty much anything – you, me, cars, planes. But we're just tiny, and space is very 'stiff' – it really doesn't like to deform. So while we do produce gravitational waves, they're minuscule in terms of amplitude. Basically, we're looking for violent things – to get a signal that's strong enough to measure on Earth, or in orbit near Earth, it really has to be a very big, violent event in the universe.

Waves are created by an acceleration of mass, so if you think of two objects orbiting each other, you can have an angular acceleration – if you have two stars orbiting and you're viewing them from a long way away, then at some times you see the two stars separated, with one gravity field, and at other times they're roughly in line with each other.

If you think of the electromagnetic spectrum, then you have radio telescopes and X-ray telescopes. They're very different instruments, but they're still measuring parts of the electromagnetic spectrum. It's just to

do with the frequency of the waves, and with gravitational waves it's exactly the same. With Earth-based detectors you're measuring high-frequency waves from things that are oscillating hundreds or thousands of times a second, while with space-based detectors you might be looking at things that change over thousands of seconds – six orders of magnitude difference in frequency.

Gravitational wave experiments like the Laser Interferometer Gravitational-Wave Observatory and Virgo are looking for events involving stellar-mass objects – things like neutron stars, supernovae and stellar black holes, up to about ten times the mass of the Sun. But up in space we're hoping to look for the really big guys – things like galaxies smashing into each other, 10-million-solar-mass black holes and stuff like that.



Dr Paul McNamara, project scientist on the European Space Agency's LISA Pathfinder mission

SEARCH FOR LIFE

When we search for extraterrestrial intelligence, what are we looking for?

In the past 70 years or so we were looking for radio signals, but the problem with that approach is that it requires the counterpart to be alive. That limits the number of civilisations you can learn about. However, if you're looking for relics that are left behind, then in principle you can see all of them. We can't have a telephone conversation with the Mayan culture – it's not around anymore – but we can look for the relics that they left behind in archaeological sites. The Sun is a latecomer; most stars formed billions of years before the Sun. Other civilisations may have perished billions of years ago, and the only way you'll find them is to look for relics that they left behind.

There are other technosignatures that we look for, but those are remote and over large distances. The advantage of debris or space junk is that, in principle, you can put your hands on it if you land on such a thing. Or if such a thing enters Earth's atmosphere

and lands as a meteorite on the ground, then you can study what technology is there and maybe import it to Earth. That could save us a million or a billion years in our own technological development – it could be worth a lot of money.

There are other ways to do it remotely. For example, looking for industrial pollution in the atmospheres of planets around other stars, or looking for photovoltaic cells that cover the dayside, artificial lights on the nightside of planets or looking for structures such as a Dyson sphere or swarm of satellites.

There are lots of different ways, and our imagination is limited by the technologies that we develop. As we develop more and more, we'll have more to search for, because that will expand our imagination. But the archaeology part I think is already here, and it's something we should do.



Dr Abraham Loeb, theoretical physicist and the Frank B. Baird Jr. professor of science at Harvard University, where he is also director of the Black Hole Initiative and the Institute for Theory and Computation

🔭 Telescopes around the world are listening out for alien signals

FOCUS ON

YOUNG STARS CAUGHT BELTING HIGH-ENERGY GAMMA RAYS FOR THE FIRST TIME

The discovery represents the first evidence that low-mass T Tauri stars, which are less than 10 million years old, can emit gamma radiation

Reported by Josh Dinner

Astronomers have witnessed a young, Sun-like star blasting out high-energy gamma radiation for the first time. The observation represents the first evidence that this type of low-mass star – called a T Tauri star – surrounded by a planet-forming disc of gas and dust, can emit gamma radiation. In a nutshell, this type of radiation represents the most energetic form of light. Down the line, these findings could have important implications for our understanding of stars and planetary systems during their formative years.

“This observational evidence is essential for understanding the origin of sources that have previously remained unknown for more than a decade, which is unquestionably a step forward in astronomy,” Agostina Filócomo, discovery team leader and an astronomer at the Universidad Nacional de La Plata, said. “It is also critical to comprehend the processes that occur during the early phases of star formation. If a T Tauri star produces gamma-ray radiation, it will affect the gas conditions of the protoplanetary disc, and consequently the evolution of planet formation.”

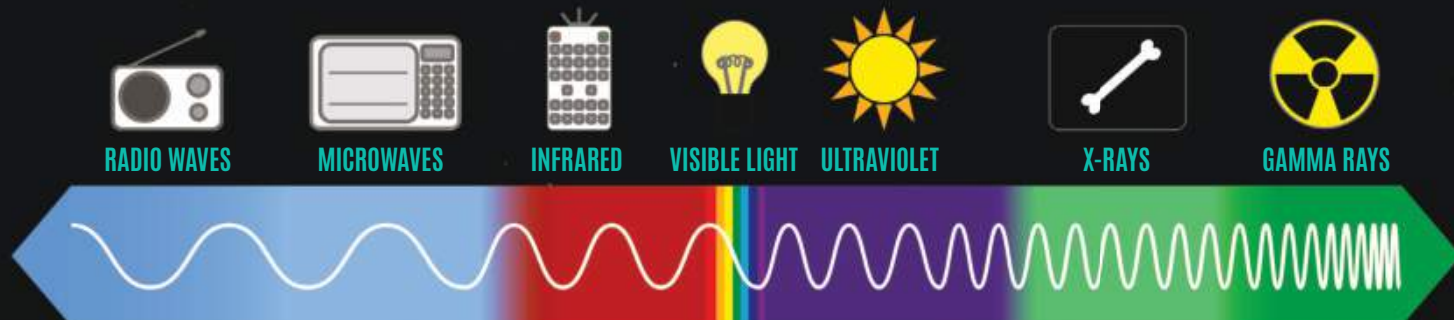
The astronomers captured their observations of this intriguing star with the Fermi Gamma-ray Space Telescope, which observes the universe in gamma rays. In

other words, this telescope has the ability to collect high-energy radiation data that can be tough to gather from the surface of Earth. Fermi has been observing the sky since it launched in 2008, but about 30 per cent of the gamma rays it has seen have yet to be attributed to a source. Filócomo and her team set about attempting to identify some of these mysterious sources.

The research team found that many gamma rays appear to originate from regions with actively forming stars. This is something that defied explanation, and thus required deeper investigation, with the team honing in on the star-forming region NGC 2071. In particular, Filócomo and colleagues looked for T Tauri stars in NGC 2071, which lies in the northern part of the molecular cloud Orion B, located around 1,370 light years from Earth. T Tauri stars are notable because they are often found near star-forming regions, still cocooned in the very gas and dust that created them. And because they are shrouded in these gaseous cradles, T Tauri stars exhibit fluctuating levels of brightness, making them a type of variable star.

Three different unidentified gamma-ray sources that seemed to be coming from the direction of NGC 2071 were found, where at least 58 T Tauri stars are known to be currently forming. There are no other objects in the region that could be sources of gamma-ray emissions. The team thinks T Tauri stars could be emitting gamma rays sporadically during powerful flare events called ‘megafares’, which occur when magnetic energy stored in the atmospheres of young stars gets released in the form of powerful electromagnetic bursts. This concept is similar to the way solar flares are launched by the Sun, except they occur on a radically larger scale. Megafares can

THE ELECTROMAGNETIC SPECTRUM



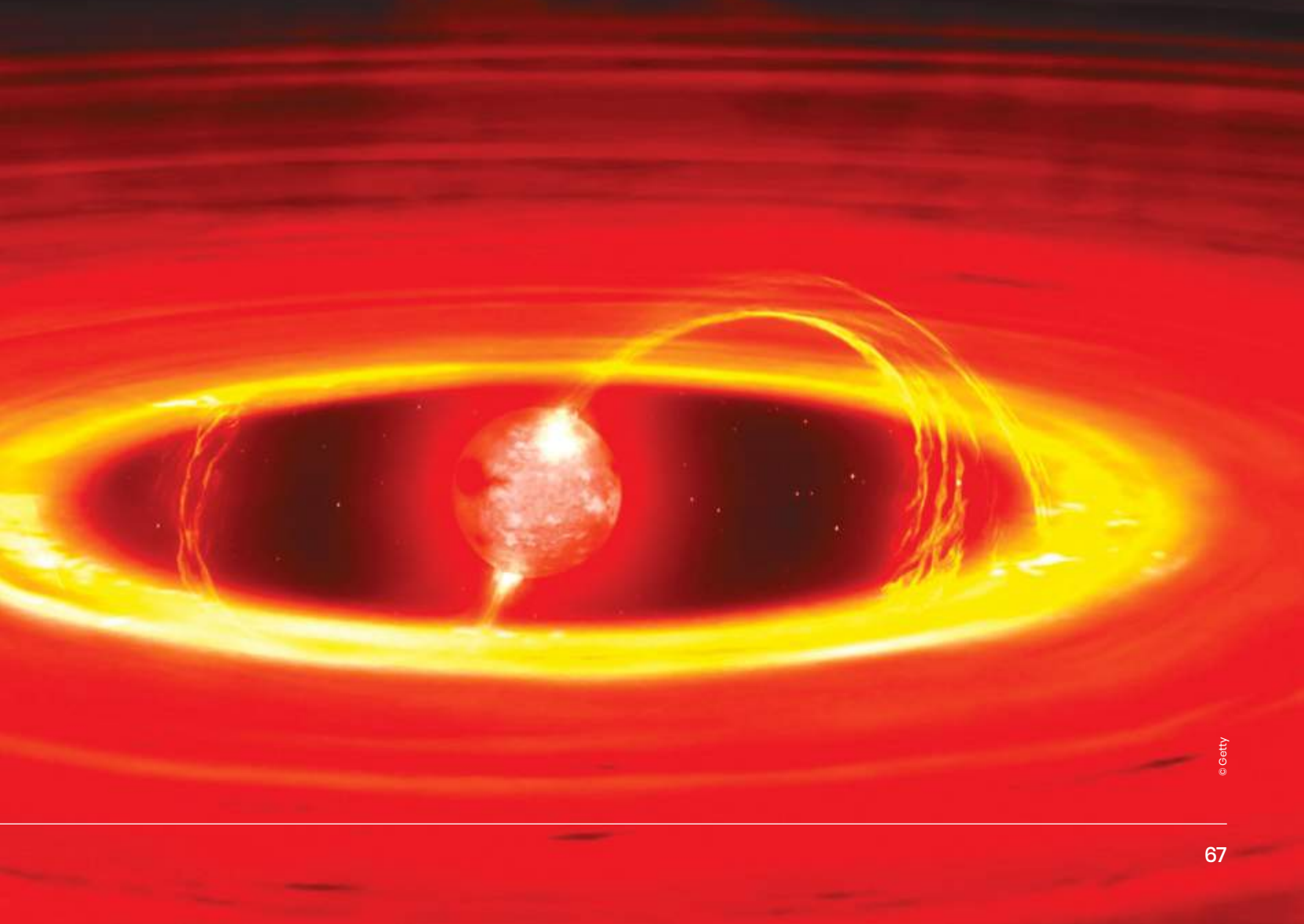
stretch for distances equivalent to several times the radius of the stars that launch them in the first place and are so powerful that if the Sun were to blast out such an eruption, life on Earth would be threatened.

Yet despite this destructive potential, some scientists argue that megafares in the early history of the Solar System, when the Sun was embedded in a disc of gas and dust, may have actually been beneficial to

planet birth by driving gas and triggering the formation of pebbles and other small rocky materials. As such, not only could the team's findings help account for previously unattributed gamma-ray detections, but could have implications for our understanding of the Solar System – especially during the period when our planet was being created. "The discovery of this phenomenon serves to understand how not only the Sun but also our home planet, Earth, were formed and evolved," Filócomo concluded.

▲ Light is a spectrum, and the human eye can only detect parts of this

▼ Young stars are usually surrounded by a disc of gas and dust, from which planets can form



THE NIGHT SKY IN

The most exciting
and fascinating
events you can
observe next year

Written by Stuart Atkinson

2024

As Earth turns on its axis, and as it whirls around the Sun, our view of the universe changes. Stars and constellations come and go; the planets move across the sky; comets appear in the sky then fade away; astronomical bodies align to cause occultations, or eclipses and shooting stars skip across the sky, sometimes large numbers of them in a short time, causing a meteor shower. During the year ahead there will be lots of fascinating things to see – and this special **All About Space** guide will help you to see them.

12 January

MERCURY IS AT ITS GREATEST SEPARATION FROM THE SUN

Mercury is the closest planet to the Sun, taking just 88 days to whip around it once compared to the 365 days it takes Earth to make one orbit. Mercury never strays very far from the Sun in the sky – we only ever see it for a short time before sunrise, or briefly after sunset, embedded in a marmalade-hued twilight sky. Often it gets lost in that twilight, but when it moves far away from the Sun we

can see it quite clearly with the naked eye. If you go out at around 05:30 on the morning of 12 January you'll see a copper-hued spark of light very low in the eastern sky – this is Mercury. If you can't see it, try scanning the sky with a binocular and it should pop into view. But don't look once the Sun has risen, as that is very dangerous and you might blind yourself by accidentally looking at the Sun.

7 February

THE MOON SHINES NEAR VENUS BEFORE SUNRISE

If you're a night owl or an early riser who heads out to work before the crack of dawn, head outside around 07:00 on the morning of 7 February, and if the sky is clear you'll see a beautiful celestial pairing low in the southeast. Shining above and to the left of a very thin waning crescent Moon you'll see Venus, shining like a bright 'star'. The two should be clearly visible to your naked eye, but if you can't quite pick them both out, a binocular should snap them into view.

14 February

THE MOON IS CLOSE TO JUPITER IN THE SKY

As darkness falls on the evening of 14 February, many of us will be pulling on our jackets and coats and heading out for a romantic Valentine's Day meal, or settling down at home for a quiet night in to celebrate in private. But before you go out, or get too comfortable inside, take a moment to go outside and look at the sky. Over in the southwest, where the sky is darkening after sunset, you'll see the lovely crescent of a waxing Moon and a bright 'star' shining to its upper left. This is Jupiter, the largest planet in the Solar System. The pairing will be visible through the evening before setting at around midnight.



▲ Comet NEOWISE shining in the night sky in 2020

March

COMET 12P/PONS-BROOKS SHOULD BE VISIBLE

Comets aren't rare visitors to our night sky. Comets bright enough to be seen with the naked eye or binoculars are rare, but there are literally dozens of comets visible in the night sky each and every night – they're just so small and faint you need a binocular or telescope to see them. This month a comet called Pons-Brooks might become bright enough to be seen with binoculars. This comet travels around the Sun once every 71 years, and was last seen in 1954. During March the comet will move from Andromeda into Aries, and should be easily visible through binoculars.



◀ 'Markarian's Chain' of galaxies in Virgo

March

GALAXY SEASON BEGINS

Every season has its own sky, with objects only visible during that season. Although the winter sky is unquestionably lovely, with all its brightly coloured, jewel-like stars and bold constellations, the spring sky is the favourite of many observers because its constellations contain lots of faint and intriguing galaxies for them to track down with their telescopes when the tempestuous spring weather allows. In March they swing those telescopes towards the constellations of Leo and Virgo, which are both sprinkled very generously with galaxies.

25 March

PENUMBRAL LUNAR ECLIPSE

On the morning of 25 March, as the eastern sky is brightening with the approach of sunrise, something unusual will be happening over in the western part of the sky as the Moon drops down towards the horizon. At around 04:55, the Moon will begin to drift through Earth's shadow, and its bright face will start to dim. This is a lunar eclipse, but this won't be one of those where the Moon famously turns bright orange or deep red. This time the Moon is only going to pass through the fainter outer part of Earth's shadow, the penumbra, so will only be darkened by a small amount.



▲ A penumbral lunar eclipse is much less dramatic than a total lunar eclipse

8 April

A TOTAL SOLAR ECLIPSE VISIBLE FROM THE UNITED STATES

When the Moon passes directly between Earth and the Sun, it covers the Sun's disc, turning it into a pitch-black hole in the sky surrounded by a ghostly haze. The total phase is short, lasting between a few seconds to a few minutes, but it's magical, and on 8 April millions of people across North America will be able to witness it. Unfortunately this spectacle won't be visible from the UK, but observers in Ireland and the western regions of Scotland will be able to see a partial eclipse, with around a quarter of the Sun's disc covered by the Moon. Frustratingly this will happen just before sunset, with the Sun just a few degrees above the horizon, making it very hard to see, and it will only be visible safely through special eclipse glasses or telescopes fitted with solar filters.

▲ Mercury as seen by the MESSENGER space probe

24 March

MERCURY IS AT ITS GREATEST SEPARATION FROM THE SUN IN THE EVENING SKY

Mercury is easiest to see when it's at its farthest point from the Sun, and that will happen again this month, specifically after dark on the evening of 24 March, when it will be shining low in the west as the sky grows dark. Mercury will look like an orange-hued 'star' to the lower right of much brighter and more obvious Jupiter, and it won't set until almost two hours after the Sun. Again, if you can't see it when you start looking, try scanning the western sky with a binocular and it should eventually pop into view.

10 April

THE MOON, TWO PLANETS AND A COMET MEET IN THE EVENING TWILIGHT

After sunset on the evening of 10 April, there will be something very rare to see low in the western sky: the Moon, a pair of planets and a comet will all be gathered close together, forming a triangle. The Moon will be a thin crescent, barely more than a sliver, shining to the upper right of Jupiter, which will look like a bright blue-white 'star', visible to the naked eye. Close to Jupiter, to its upper left, will be Uranus, visible through binoculars as a green speck. 12P/Pons-Brooks will be to the lower right of the Moon and Jupiter, possibly bright enough to be visible to the naked eye but almost certainly bright enough to be seen through binoculars. The best views will be after 21:00.

12 April

COMET 12P/PONS-BROOKS IS CLOSE TO JUPITER IN THE SKY

Two days after that celestial gathering, the Moon will have moved out of the way, shifting eastwards on its track across the sky. Comet 12P/Pons-Brooks will have moved closer to Jupiter, and the pair should just about be visible through binoculars at the same time. We can't know this far in advance how bright the comet will be, but it might be bright enough to be visible as a smudge to the naked eye. If it undergoes 'outbursts' of activity, as it has done in the past, it might be easily visible without optical aid, but we'll have to wait and see. However bright the comet is, it will be fascinating to see it so close to beautifully bright Jupiter in the evening twilight.

➤ If Comet Pons-Brooks undergoes an outburst, it might look like Comet Holmes did in 2007

21 April

COMET 12P/PONS-BROOKS REACHES ITS MAXIMUM PREDICTED BRIGHTNESS

Comet watching can be very frustrating. Many are only visible for very short periods, low in the sky or close to the Sun, and unlike stars and planets their peak brightnesses can't be predicted with great accuracy either. Comets predicted to be easily visible to the naked eye sputter out and can only be seen through telescopes, while comets expected to be mere smudges in binoculars can brighten enough to be visible without them. Comet Pons-Brooks is expected to reach its maximum brightness of magnitude +4.5 on the evening of 21 April, when it will be very low in the western twilight after sunset, to the lower left of Jupiter.

🕒 During a total solar eclipse, the Sun's atmosphere, or corona, can be seen shining around it

4 May

A CRESCENT MOON CLOSE TO SATURN BEFORE SUNRISE

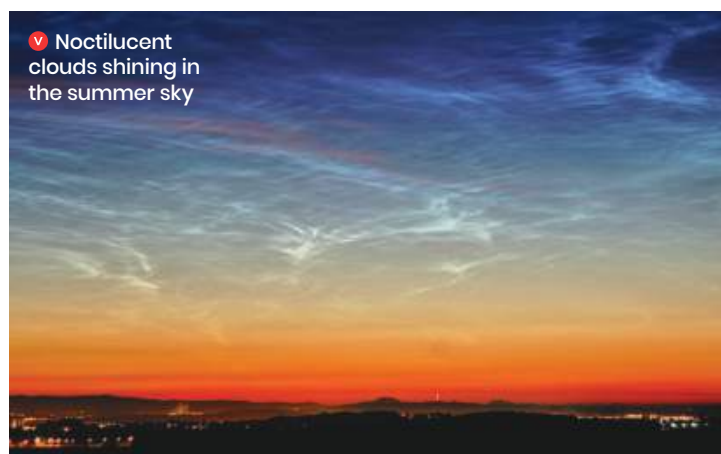
Early on the morning of 4 May there will be an opportunity to see Saturn shining close to the Moon in the predawn sky. In a dark sky, Saturn, famous for its beautiful, icy rings, is clearly visible to the naked eye as a golden-hued star. On 4 May it will be harder to see, very low in the east as the sky brightens quickly with the approach of sunrise. You might actually need to use a binocular to pick it out in the sky, shining a short distance away from the waning crescent Moon to its upper left. However, if you want to see those famous rings you'll need a telescope, as binoculars aren't powerful enough to show them.

June

NOCTILUCENT CLOUD SEASON BEGINS

Understandably, amateur astronomers hate clouds. They cover up all the fascinating objects visible in the night sky and stop us from seeing the meteor showers, eclipses, comets and displays of the northern lights we look forward to with such excitement. However, there is one type of cloud many stargazers actually look forward to seeing. Noctilucent clouds only appear in the summer months. Some astronomers dismiss noctilucent clouds as 'just clouds', but many others think they are one of

the most beautiful sights in astronomy. They are clouds of icy dust high in the atmosphere, on the very edge of space, and appear in the night sky as billows, tendrils, streaks and plumes of electric silvery-blue low in the north, usually after midnight. Unlike aurorae, their appearance can't be predicted with much confidence or accuracy, but you can receive alerts by following noctilucent cloud-watching groups on social media. Be prepared to stay up until the early hours to see the best displays.

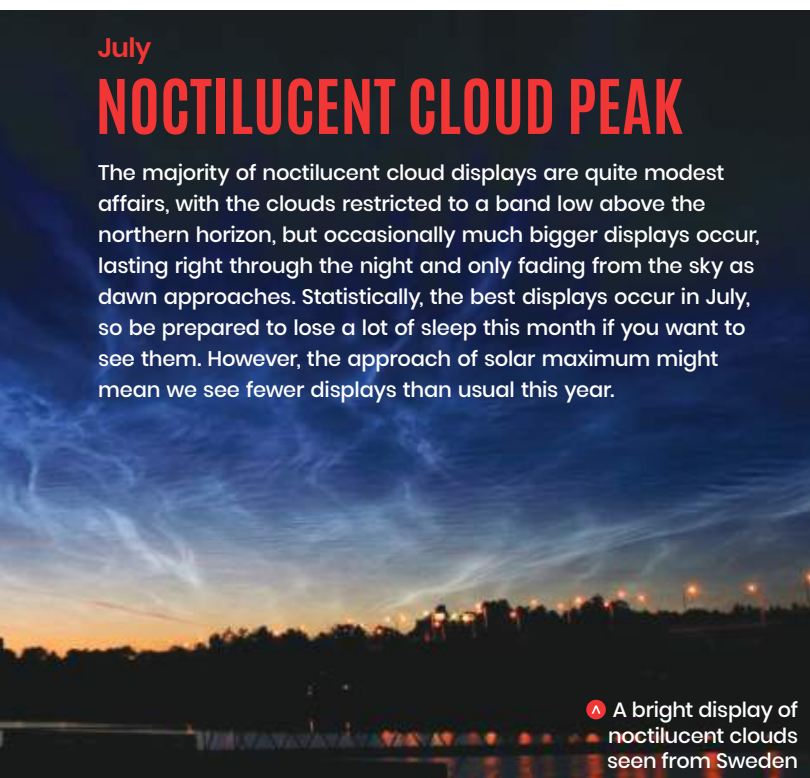


✓ Noctilucent clouds shining in the summer sky

July

NOCTILUCENT CLOUD PEAK

The majority of noctilucent cloud displays are quite modest affairs, with the clouds restricted to a band low above the northern horizon, but occasionally much bigger displays occur, lasting right through the night and only fading from the sky as dawn approaches. Statistically, the best displays occur in July, so be prepared to lose a lot of sleep this month if you want to see them. However, the approach of solar maximum might mean we see fewer displays than usual this year.



▲ A bright display of noctilucent clouds seen from Sweden



3 June

THE MOON IS NEAR MARS IN THE MORNING SKY

When it's shining high in a dark sky, Mars is a striking sight. It looks like a bright-orange 'star' in the darkness, and can't be mistaken for anything else. That will be the case later in the year, but during June Mars will be a faint object low in the east before sunrise, fighting to be seen in the brightening sky. However, on the morning of 3 June the Red Planet will be easy to see as it will be shining very close to the Moon, to its lower right, and you'll be able to see them both together in the same binocular field of view. The Moon itself will be a beautifully slim crescent, so the pair will be a lovely sight before the dawn sky overwhelms them.

3 July

THE CRESCENT MOON IS CLOSE TO THREE PLANETS AND THE PLEIADES

Get up early, go out and look to the northeast just after 03:00 and you'll see a lovely waning crescent Moon shining low in the sky, just above bright, star-like Jupiter. Look more closely and over to the right of the Moon you'll see the planet Mars, looking like an orange-hued 'star', much fainter than Jupiter but still clearly visible to the naked eye. If you have a binocular handy, look halfway between the Moon and Mars and you'll be able to see another planet, Uranus, as a very faint, slightly green-hued 'star'. You'll also be able to see the famous Pleiades, or 'Seven Sisters', close to the Moon, just to its upper right.

7 July

MERCURY IS CLOSE TO THE MOON IN THE EVENING TWILIGHT

The planets Venus, Jupiter, Saturn and Mars are all easily visible to the naked eye and are on view for months at a time. Mercury is visible to the naked eye too, but it is much more elusive and challenging because it orbits so close to the Sun that it never spears far from it in the sky, and can only be seen before sunrise or after sunset for brief periods. After sunset on the evening of 7 July, Mercury will be easier than usual to spot because it will be shining directly below an extremely thin crescent Moon, low in the northwest. If you can't find the pair right away, look for brighter Venus down near the horizon, then look to its upper left. You might need a binocular to pick the close pair out of the bright twilight.

30 July

THE MOON, MARS, ALDEBARAN, THE PLEIADES AND JUPITER GATHER

The end of July will see a very special gathering of celestial objects in the eastern sky before dawn. To see this cosmic parade, go out around 03:00 and look to the east, where straight away you'll see a lovely waning crescent Moon shining in the sky. Look more closely and you'll see the Pleiades star cluster close to the Moon, to its upper left. Mars is directly beneath it, looking like an orange star, with Jupiter shining brightly to the lower left of Mars and the V-shaped Hyades star cluster forming a triangle with Jupiter and Mars, all clearly visible to the naked eye. If you have a binocular you'll also be able to see the planet Uranus to the right of the Moon, looking like a faint, pale-green star.



▲ The Milky Way seen from a dark-sky location with no light pollution

Late July

MILKY WAY VIEWING OPPORTUNITIES

There are always some parts of the Milky Way visible whatever time of year it is, but the brightest and most dense parts of the Milky Way are visible in the Northern Hemisphere's sky from the end of June into early September, when they can be seen low in the south late in the evening. This is when skywatchers swing their telescopes towards the frothy star clouds of Sagittarius and Scorpius and track down famous southerly nebulae and star clusters – such as the Lagoon and Trifid and the globular star cluster Messier 4 – that are hidden beneath the horizon for the rest of the year.

21 August

LUNAR OCCULTATION OF SATURN

Skywatchers all across the UK will spend much of 20 August checking the weather forecast, and will go to bed that night hoping desperately for clear skies the following morning so they can see a very rare event: the planet Saturn being covered, or 'occulted', by the Moon. The last time this was visible from the UK was in 2007, so a cloudy sky at 04:30 on the morning of 21 August will be disastrous. That's when the famously Ringed Planet will start to vanish behind the limb of the Moon, not to reappear again until around 05:15. To the naked eye and through binoculars it will look like Saturn has blinked out of view as it vanishes behind the Moon almost instantly, but through a telescope the view will be stunning, as the disc and the rings of the planet slide slowly and silently behind the Moon's curved limb.



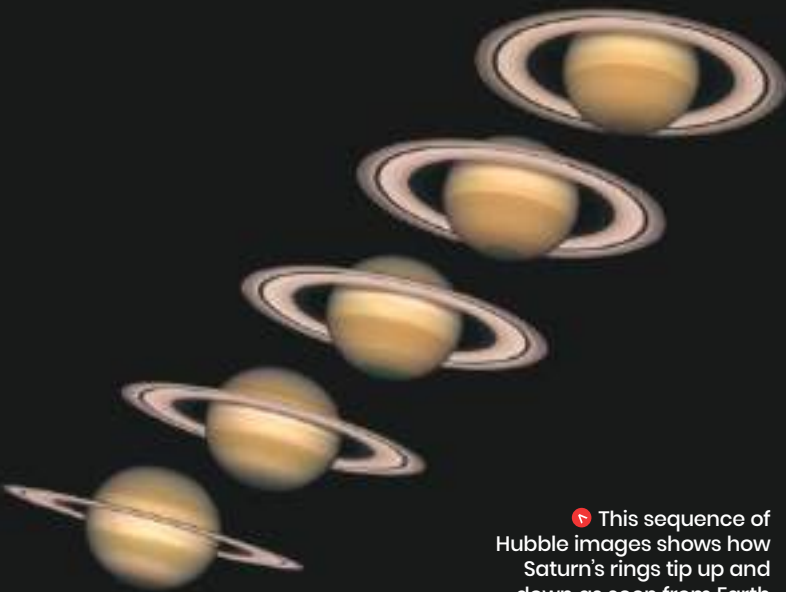
September

THE AUTUMN CONSTELLATIONS RETURN

Unlike most people, stargazers look forward to the end of summer because it means the return of dark, starry skies after several long months of almost-endless twilight. At the start of September the Sun sets at 20:00, meaning the sky is dark enough by 21:00 to begin some serious stargazing and observing. The Milky Way is still clearly visible as a band of misty light cutting the sky in half and stretching overhead, running from the northeast to the southwest, but most stargazers turn their eyes and telescopes to the east, where autumn constellations such as Perseus, Andromeda and Pegasus are returning to the sky, with their many star clusters, nebulae and galaxies.

▶ In autumn the constellation Andromeda, and its galaxy, are well placed for viewing

© Alamy / Getty



🔍 This sequence of Hubble images shows how Saturn's rings tip up and down as seen from Earth

8 September

SATURN AT OPPOSITION

Saturn is famous for its beautiful system of icy rings, but if you turn a telescope towards Saturn in September, when it is at opposition – opposite the Sun in the sky – you might be forgiven for wondering where they've gone. As Saturn and Earth move around the Sun in their orbits, Saturn appears to slowly tip up and down from our point of view, so sometimes the rings are wide open and other times we see them at such a shallow angle that they appear to close up until they are edge-on to us and they vanish, reduced to a mere line across the planet's disc. During September the rings will be very narrow, and gradually closing, so catch them while you can.



🌑 During a partial lunar eclipse, only part of the Moon is in Earth's shadow

18 September

PARTIAL LUNAR ECLIPSE

Lunar eclipses are caused when the Moon moves through the shadow cast through space by Earth. During a total lunar eclipse the whole of the Moon's disc can turn a dark, muddy red or a striking orange colour. As the name suggests, during a partial lunar eclipse only part of the disc is darkened, and this is what will happen in the early hours of 18 September. Observers across Europe, Africa and the Americas will see the

first signs of the dark shadow of Earth falling onto the Moon at around 03:15, and the eclipse will reach its peak half an hour later. However, only eight per cent of the Moon will be in Earth's shadow, so all we'll see will be a dark 'notch' taken out of the upper right of its disc before the Moon eases back out of the shadow and returns to normal at 04:15. This event will be best seen through binoculars and telescopes.

28 September

COMET TSUCHINSHAN-ATLAS AT FIRST MAGNITUDE BEFORE SUNRISE

There's a chance – but only a chance – that by the end of September there will be a comet in the sky bright enough to be seen with the naked eye. Comet Tsuchinshan-ATLAS caused great excitement when it was discovered in 2023, because when the numbers of its orbit were crunched they suggested that it might become a very bright naked-eye comet. Hopefully we'll be able to see the comet with the naked eye at the end of this month, low in the east before sunrise beneath the Sickle asterism of Leo, but its low altitude and proximity to the Sun will dim it considerably, and it might be a binocular or telescope object. Of course, it might surprise us and grow a long, bright tail, but we'll have to wait and see...



🔍 Comet NEOWISE was visible in 2020

2 October

ANNULAR SOLAR ECLIPSE

A very rare and beautiful astronomical event will take place on 2 October. Unlike a total solar eclipse, when the Moon completely covers the Sun's disc, during an annular eclipse the Moon is too far away from Earth to cover the whole of the solar disc. A ring, or 'annulus', of sunlight is left around it, often called a 'ring of fire'. Although this ring is very thin, it's still more than bright enough to blind anyone looking at the Sun through binoculars or telescopes that aren't fitted with filters during the eclipse. The eclipse will only be visible from Easter Island and the southern tip of South America.



🔍 A 'ring of fire' annular solar eclipse

13 October

COMET TSUCHINSHAN-ATLAS MIGHT BE VISIBLE IN THE EVENING SKY

Having shone low in the predawn sky earlier in the month, Comet Tsuchinshan-ATLAS will now move into the evening sky. After whipping around the Sun, the comet will appear low in the west as twilight deepens, between the bright star Arcturus and the much brighter planet Venus, which will be very low in the southwest after sunset. There have been some crazy predictions about how bright the comet might appear, but they should all be taken with a grain of salt. For a start, the comet might not even survive its fiery solar flyby, and could disintegrate like Comet ISON famously did. However, if it does survive it will be worth looking for in the evening twilight from the middle to the end of October, even if it's only visible through binoculars as a smudge. If it grows a long tail it might be quite impressive, but we just can't know that in advance.

👉 Try to catch the supermoon as it's rising to see it at its best



👉 Will this comet be as bright as Comet NEOWISE was in 2020?



👉 The Leonid meteor storm of 1833

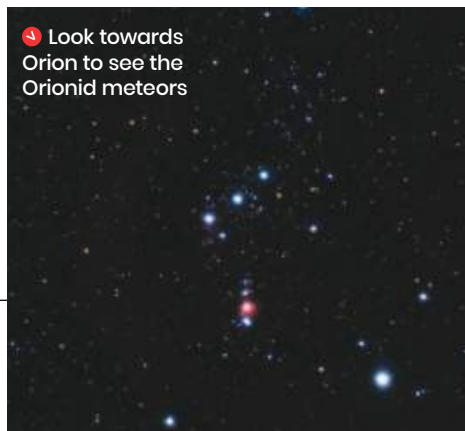


21 October

PEAK OF THE ORIONID METEOR SHOWER

One of the best meteor showers of the year is the Orionids, which peak in late October every year. As the name suggests, during this shower meteors appear to shoot out of a point in the constellation of Orion, and on a good year we can expect to see 20 or so meteors every hour as pieces of dust shaken off from the icy nucleus of Halley's Comet burn up in the atmosphere. Unfortunately, 2024 will not be a good year for the Orionids, because a big bright Moon will be blazing in the sky all through its peak, but if your sky is clear late on the evening of the 21st you should still go out and look towards the east, because the brightest meteors will shine through the moonlight.

👉 Look towards Orion to see the Orionid meteors



17 November

PEAK OF THE LEONID METEOR SHOWER

In mid-November every year, Earth passes through a stream of space dust left behind by a comet called Tempel-Tuttle. As these dusty particles burn up in the atmosphere, we see a streak of light across the sky – a meteor, or shooting star. As we pass through the most dense part of the stream overnight on 17 November, we see meteors known as the Leonids, because the shooting stars appear to zip out of the constellation of Leo. Every 33 years or so the Leonids have a burst of activity, and can produce a storm of thousands of meteors an hour. 2024 isn't one of those years, and it will be a poor year in general because yet again there will be a big, bright Moon in the sky drowning out all but the brightest meteors. But if you go out after midnight on the 17th you might still see a few bright meteors dashing out from Leo.

17 October

LARGEST AND BRIGHTEST SUPERMOON OF THE YEAR

The term 'supermoon' divides astronomers. Some think it's just over-hyping what is essentially a slightly-larger-than-usual Moon and giving non-astronomers false expectations. Others think it's just a bit of fun, and if it gets people looking at the sky it has to be a good thing. Whichever side you agree with, the largest and brightest supermoon of the year will occur on the evening of 17 October, when the Moon will lie 357,367 kilometres (222,057 miles) from Earth. If you go out and see it rising it will indeed look bigger and brighter than usual, and will look very beautiful from a dark-sky location especially, but it won't cover half the sky or dazzle you like some websites would have you believe.

December

RETURN OF ORION AND THE WINTER STARS

The autumn sky has many attractions, including some beautiful telescopic sights, but stargazers always look forward to December because that's when they can welcome the big, bright and colourful winter stars and constellations back to their sky. As December begins the Sun is setting early enough to allow stargazing to begin in the early evening, and even from a light-polluted back garden the winter sky seems strewn with many more stars than autumn's.

➔ Orion dominates the winter sky



➔ Jupiter and its famous Great Red Spot, taken by the Hubble Space Telescope

7 December

JUPITER AT OPPOSITION

Even though Jupiter is so far away that its light takes 34 minutes to reach us, it is so huge that we can see it in our sky with the naked eye, looking like a bright blue-white 'star'. This month will be a great time to see this behemoth of a world, which could swallow up Earth a thousand times over, because it will be at opposition, rising as the Sun is setting and visible all night long. To see it, all you have to do is go out after sunset, turn your back on it so you're facing the northeast and there will be Jupiter, low in the sky. You'll need a telescope to see its famous Great Red Spot and the caramel-coloured cloud bands that cross its disc, but binoculars will show you some of its huge family of moons as 'stars' close to the planet.

End of December

MERCURY IS AT ITS GREATEST SEPARATION FROM THE SUN

Many skywatchers have never seen the planet Mercury, even though it is bright enough to be seen clearly with the naked eye. Mercury is the closest planet to the Sun, so unlike the other planets, which can all be seen high in a dark sky, Mercury never strays far from the Sun in the sky visually. We only ever see Mercury low in the evening sky after sunset, or low in the morning sky before sunrise. In the early hours on Christmas, before all the gift-unwrapping and cracker-pulling begins, Mercury will be a 'morning star', shining low in the southeast.

All year

METEOR SHOWERS

You can see shooting stars, or meteors, every night of the year if you're lucky enough to be looking in the right place at the right time. But at certain times of the year we can be confident of seeing more than usual, all radiating out from the same part of the sky in a meteor shower. These happen when Earth moves through a stream of dusty particles left behind by a passing comet. There are more than a dozen major showers every year, and many more minor ones. Here's a guide to the meteor showers of 2024. The number given for 'maximum number per hour' is what you would see if viewing conditions were absolutely perfect, with the radiant overhead on a dark, Moon-free night.

Quadrantids
28 December to 12 January

Date of peak: 3 January
Maximum number of meteors per hour: 120
Constellation: Boötes
Affected badly by moonlight in 2024

Lyrids
15 to 29 April

Date of peak: 23 April
Maximum number of meteors per hour: 18
Constellation: Lyra
Affected badly by moonlight in 2024

Eta Aquariids
19 April to 28 May

Date of peak: 6 May
Maximum number of meteors per hour: 55
Constellation: Aquarius
Unaffected by moonlight in 2024

Delta Aquariids
12 July to 23 August

Date of peak: 30 July
Maximum number of meteors per hour: 16
Constellation: Aquarius
Affected by moonlight in 2024

Perseids
17 July to 1 September

Date of peak: 12 August
Maximum number of meteors per hour: 100
Constellation: Perseus
Unaffected by moonlight in 2024

Draconids
6 to 10 October

Date of peak: 8 October
Maximum number of meteors per hour: 10
Constellation: Draco
Unaffected by moonlight in 2024

Orionids
2 October to 7 November

Date of peak: 21 October
Maximum number of meteors per hour: 20
Constellation: Orion
Affected badly by moonlight in 2024

Northern Taurids
13 October to 2 December

Date of peak: 12 November
Maximum number of meteors per hour: 5
Constellation: Taurus
Unaffected by moonlight in 2024

Leonids
3 November to 2 December

Date of peak: 17 November
Maximum number of meteors per hour: 15
Constellation: Leo
Affected badly by moonlight in 2024

Geminids
4 to 17 December

Date of peak: 14 December
Maximum number of meteors per hour: 120
Constellation: Gemini
Affected badly by moonlight in 2024



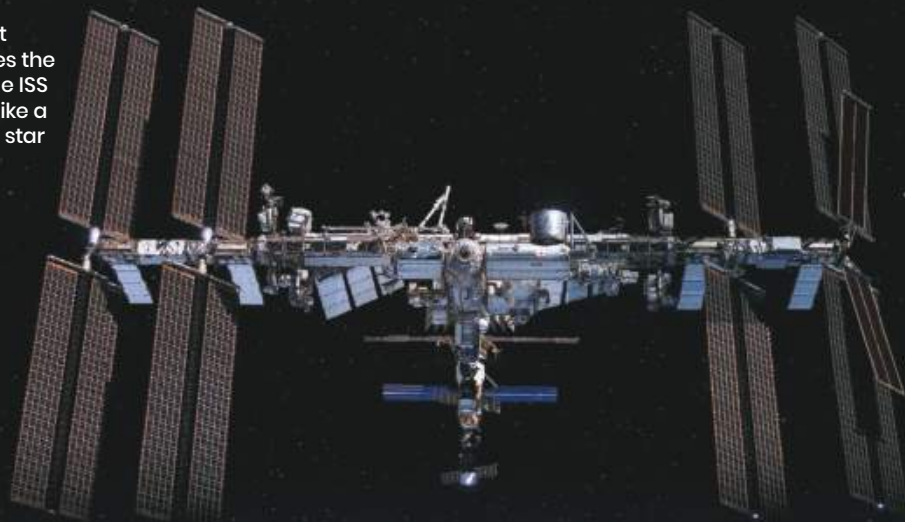


◀ As it crosses the sky, the ISS looks like a bright star

All year

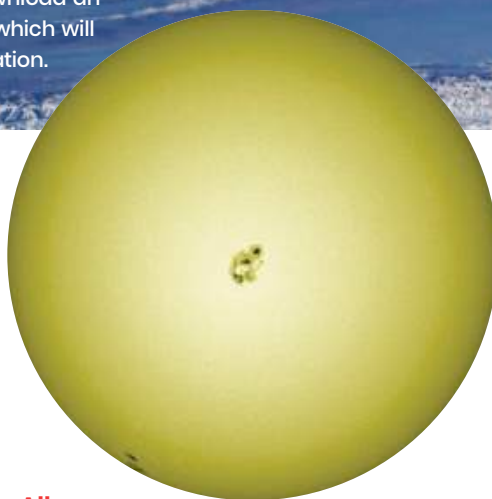
SEE THE INTERNATIONAL SPACE STATION

The International Space Station (ISS) is a wonderful scientific achievement, a huge orbital scientific outpost built piece by piece over decades where astronauts and scientists from many different countries live and work together, observing Earth and carrying out scientific experiments not possible on Earth. You can see the ISS crossing the night sky sometimes, looking like a star to the naked eye. At its brightest it can shine almost as brightly as Venus. If you want to know where and when it will be visible in your sky, you can either download an app for your phone or tablet or use websites which will calculate when it will be visible from your location.



▶ The International Space Station seen from an approaching spacecraft

▼ Sunspots on the Sun, taken using a telescope fitted with a solar filter



All year

LOOK OUT FOR THE NORTHERN LIGHTS

The northern lights, or aurora borealis, are one of nature's most spectacular sights. Caused by solar flares on the Sun sending charged particles towards Earth, which interact with our magnetic field, aurorae can look like swaying curtains of green light and pillars of blue and red. They are most frequently seen near the north pole, but occasionally can be seen further south at middle latitudes. This year there should be a lot of auroral activity as the Sun approaches 'solar maximum', its period of greatest activity. If you want to know when it might be possible to see aurorae from where you live, join groups that will alert you when a display is possible, or download aurora apps onto your tablet or phone.

◀ The northern lights shine with beautiful colours



All year

SEEING SUNSPOTS

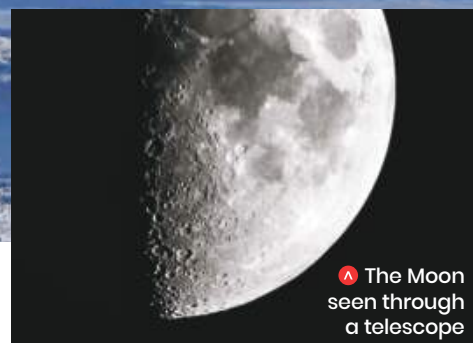
Sunspots are magnetic disturbances on the surface of the Sun – sometimes much larger than Earth – which appear like dark bruises or ink blotches on its bright face. As solar maximum approaches and the Sun's activity increases, more and more sunspots will be visible on the Sun, but special equipment and techniques are needed to see them safely. You can project an image of the Sun onto a screen using binoculars or a telescope, or you can fit a special solar filter to your telescope which will allow you to look at the Sun directly in total safety. You can also follow sunspot activity using apps or websites which show images of the Sun taken by telescopes on the ground or satellites up in space.

All year

SEEING THE MOON

It's easy to take the Moon for granted, but it's a fascinating world in its own right. To the naked eye it appears to change shape as it moves across the sky, growing from a thin, crescent new Moon hanging low in the western sky after sunset to a brilliant, round and bright full Moon two weeks later, then shrinking back to a slim crescent again in the morning sky. Binoculars will show bright impact craters and vast, dark 'seas' of frozen lava on its face, and a telescope will reveal countless jagged mountain chains, winding valleys and rays of bright debris spreading out from its largest craters. You can explore the Moon using many apps, or by using GoogleMoon, which will let you zoom in on craters and even explore the Apollo landing sites. And at the end of 2024 the Artemis II mission should carry NASA astronauts to and around the Moon for the first time in decades.

▲ The Moon seen through a telescope





FOCUS ON

STAR-STUDDED STELLAR NURSERY SHINES IN A NEW HUBBLE PHOTO

The telescope captured a massive protostar hidden behind star-forming clouds of dust and gas

Reported by Samantha Mathewson

The Hubble Space Telescope has photographed a bright stellar nursery studded with dazzling infant stars. Taken using Hubble's Wide Field Camera 3 instrument, the image captures a massive protostar called OH 339.88-1.26 lurking behind star-forming clouds of dust and gas. OH 339.88-1.26 lies an estimated 8,900 light years from Earth in the southern constellation of Ara.

During the protostellar phase, stars are still in the process of gathering mass from parent molecular clouds. Despite its young age, OH 339.88-1.26 is estimated to be about 20 times the mass of the Sun. "Winding lanes of dark dust thread through this image, which is also studded with bright stars crowned with criss-crossing diffraction spikes," European Space Agency officials said in a statement. "The dark vertical streak at the centre of this image hides OH 339.88-1.26, which is an astrophysical maser."

A maser – short for 'microwave amplification by stimulated emission of radiation' – is a naturally occurring source of stimulated spectral line emission that produces coherent light at microwave wavelengths. This type of emission has been observed in molecular clouds, comets, planetary atmospheres like that at the north pole of Jupiter and stellar atmospheres. The recent views of OH 339.88-1.26 were collected as part of

"Winding lanes of dark dust thread through this image, which is also studded with bright stars"

The European Space Agency

ANATOMY OF THE HUBBLE SPACE TELESCOPE

1 Fine Guidance Sensor

Hubble uses three fine guidance sensors – two of these are used to lock the telescope onto a target, while the third is used for astrometry.

2 Space Telescope Imaging Spectrograph

One of the most powerful instruments, this is used to cover a huge spectra of wavelengths, from ultraviolet to infrared.

3 Primary mirror

Hubble's main mirror is perfect for reflecting ultraviolet light thanks to a glass that's been coated with aluminium and a special compound.

4 Secondary mirror

The second mirror also has a special coating over its glass and is used to direct the light from the primary mirror to the instruments.

5 Aperture door

The aperture door functions as a safety valve that closes every time there's a danger that light from the Sun, Earth or Moon could pass into its mirrors.

6 Near Infrared Camera and Multi-Object Spectrometer

This is an instrument for infrared astronomy. It detects light with wavelengths from 800 to 2,500 nanometres.

7 Advanced Camera for Surveys

This was built, tested and installed long after Hubble's launch. It replaced the Faint Object Camera.

8 Cosmic Origins Spectrograph

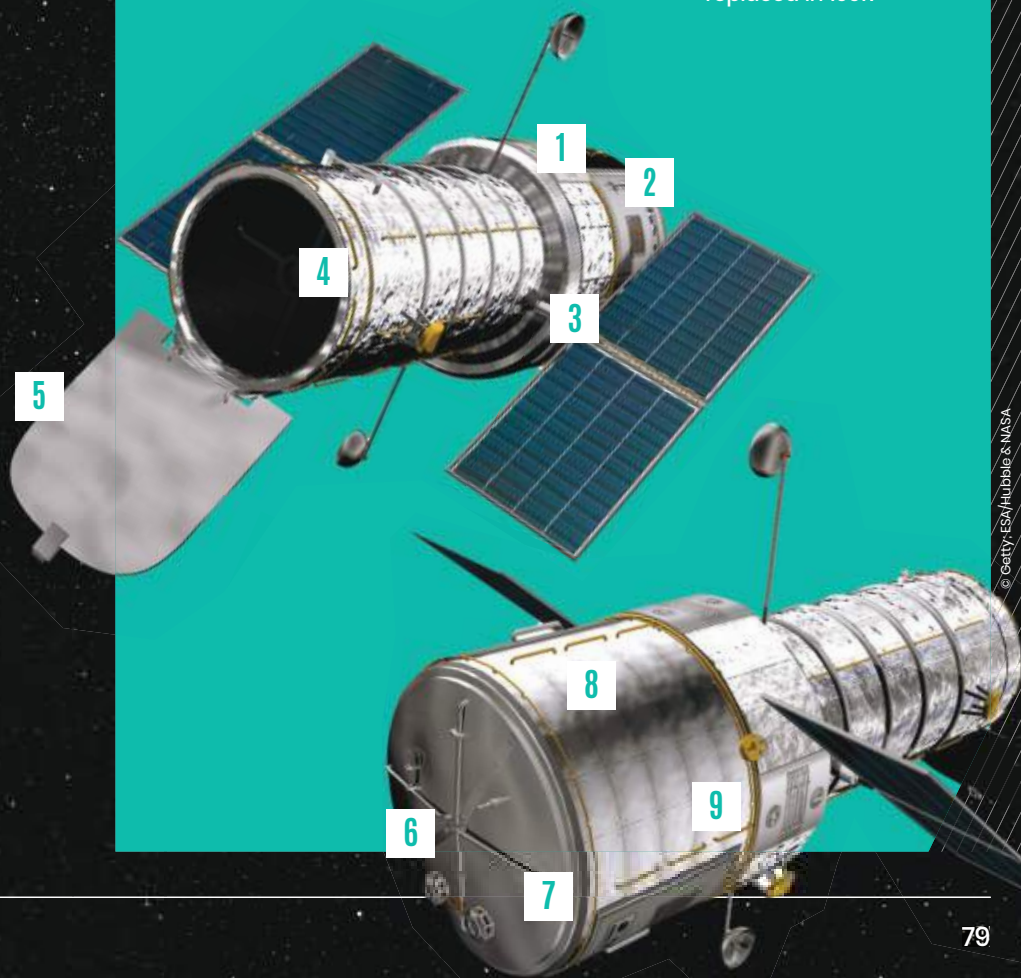
The Cosmic Origins Spectrograph is used to perform spectroscopy on faint-point sources.

9 Faint Object Spectrograph

The Faint Object Spectrograph was one of the original instruments used on Hubble. It was replaced in 1997.

an initiative to study the hearts of regions where massive stars are born to better understand the nature and formation of protostars like OH 339.88-1.26.

Observations were also taken using the ground-based Atacama Large Millimeter/submillimeter Array (ALMA) in Chile and the now-retired Stratospheric Observatory for Infrared Astronomy (SOFIA), which previously operated out of a converted 747 aircraft. ALMA comprises 66 high-precision antennae spread over distances of up to 16 kilometres (ten miles), making it the largest currently operational ground-based astronomical project. OH 339.88-1.26, cloaked by dark dust at the centre of the image, is surrounded by hundreds of stars whose bright light causes diffraction spikes from reflecting off Hubble's mirrors.



WHAT'S IN THE SKY?

What to look out for during this observing period

In this issue...

80 **What's in the sky?**
With meteor shower peaks aplenty, it's the perfect time to catch a shooting star

82 **Planetarium**
Where you can find the planets this month and the phases of the Moon

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Our destination this month is the star of one of the most famous science-fiction films ever made

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As winter looms on the horizon, relax by enjoying these celestial treats

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Turn your telescope to the Hunter and you'll be rewarded with a splendid selection of deep-sky targets

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The clocks go back at the end of this month, giving more time to view a splendour of night-sky objects

92 **Review**
We put the Sky Guide app to the test

96 **In the shops**
Our pick of the best gifts and accessories for astronomy and space fans

5 OCTOBER

The October Camelopardalid meteor shower reaches its peak



8 OCTOBER

The Draconid meteor shower reaches its peak



10 OCTOBER

The Moon and Venus make a close approach, within 5°54' of each other in Leo



11 OCTOBER

The Delta Aurigid meteor shower reaches its peak



14 OCTOBER

An annular solar eclipse is visible from the Americas



15 OCTOBER

The Triangulum Galaxy (Messier 33) is well placed in Triangulum [➤](#)



18 OCTOBER

Dwarf planet Eris reaches opposition in Cetus, glowing at magnitude +18.6



Red-light friendly

In order to preserve your night vision, you should read our observing guide under red light

22 OCTOBER

Venus reaches half phase



24 OCTOBER

Venus is at greatest elongation west in the morning sky at -4.4



24 OCTOBER

The Moon and Saturn pass within 2°32' of each other in Aquarius



27 OCTOBER

The Perseus Double Cluster (NGC 869 and NGC 884) is well placed in Perseus [▲](#)



28 OCTOBER

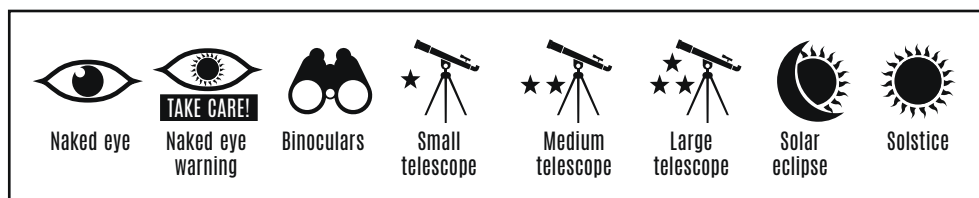
A partial lunar eclipse is visible from any location where the Moon is above the horizon



29 OCTOBER

The Moon and Jupiter make a close approach, within 2°53' of each other in Aries





10 OCTOBER

The Southern Taurid meteor shower reaches its peak



18 OCTOBER

Venus is at its highest altitude in the morning sky, dazzling at magnitude -4.4



18 OCTOBER

The Epsilon Geminid meteor shower reaches its peak



21 OCTOBER

The Orionid meteor shower reaches its peak



22 OCTOBER

Comet 2P/Encke will make its closest approach to the Sun, reaching $+6.2$ in Virgo



24 OCTOBER

The Leonis Minorid meteor shower reaches its peak



29 OCTOBER

The Moon and Messier 45 pass within $59.3'$ of each other in Taurus



1 NOVEMBER

Jupiter's orbit causes the planet to reach its closest point to the Earth



"2P/Encke will make its closest approach to the Sun"

Jargon buster

Conjunction

An alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Declination (Dec)

How high an object will rise in the sky. Like Earth's latitude, Dec measures north and south in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and 60 arcminutes in a degree.

Opposition

When a celestial body is in line with Earth and the Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Right Ascension (RA)

RA is to the sky what longitude is to Earth, corresponding to east and west. It's measured in hours, minutes and seconds, as since Earth rotates on its axis we see different parts of the sky throughout the night.

Magnitude

An object's magnitude tells you how bright it appears from Earth, represented on a numbered scale. The lower the number, the brighter the object. A magnitude of -1.0 is brighter than $+2.0$.

Greatest elongation

When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongation and as morning stars during western elongation.

STARGAZER



PLANETARIUM

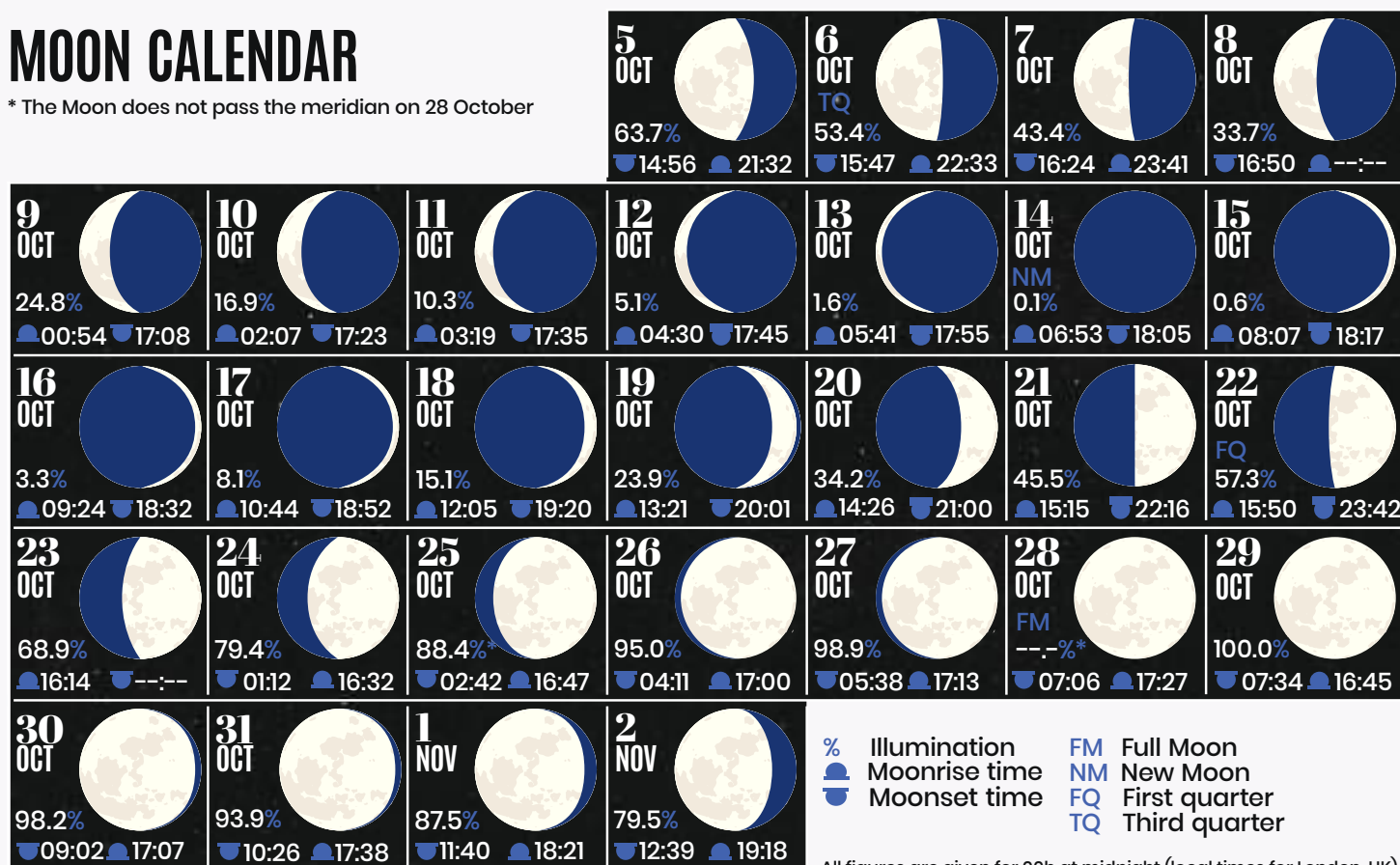
19 OCTOBER 2023

MORNING SKY

OPPOSITION

MOON CALENDAR

* The Moon does not pass the meridian on 28 October

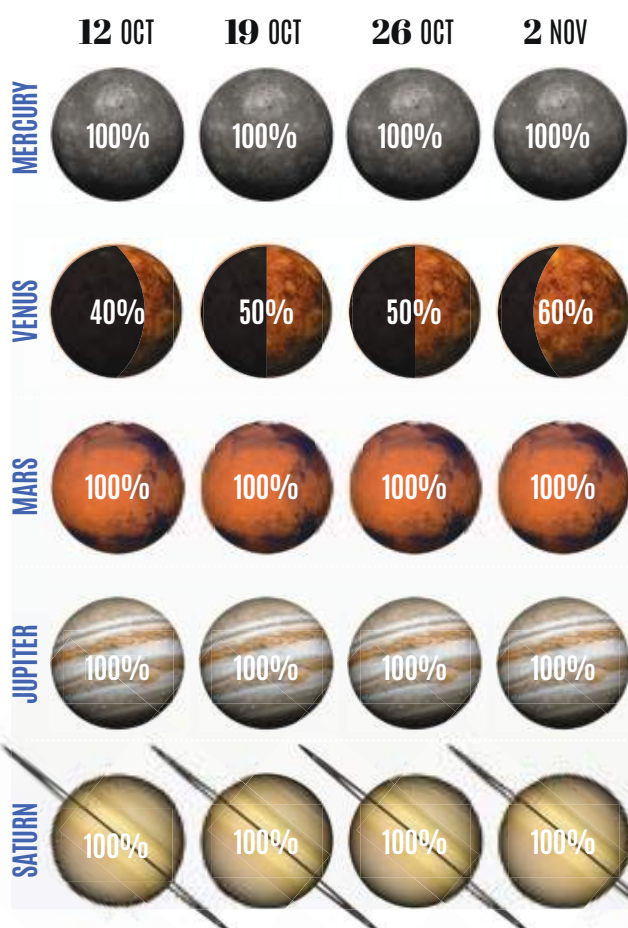




EVENING SKY

DAYLIGHT

ILLUMINATION PERCENTAGE



PLANET POSITIONS

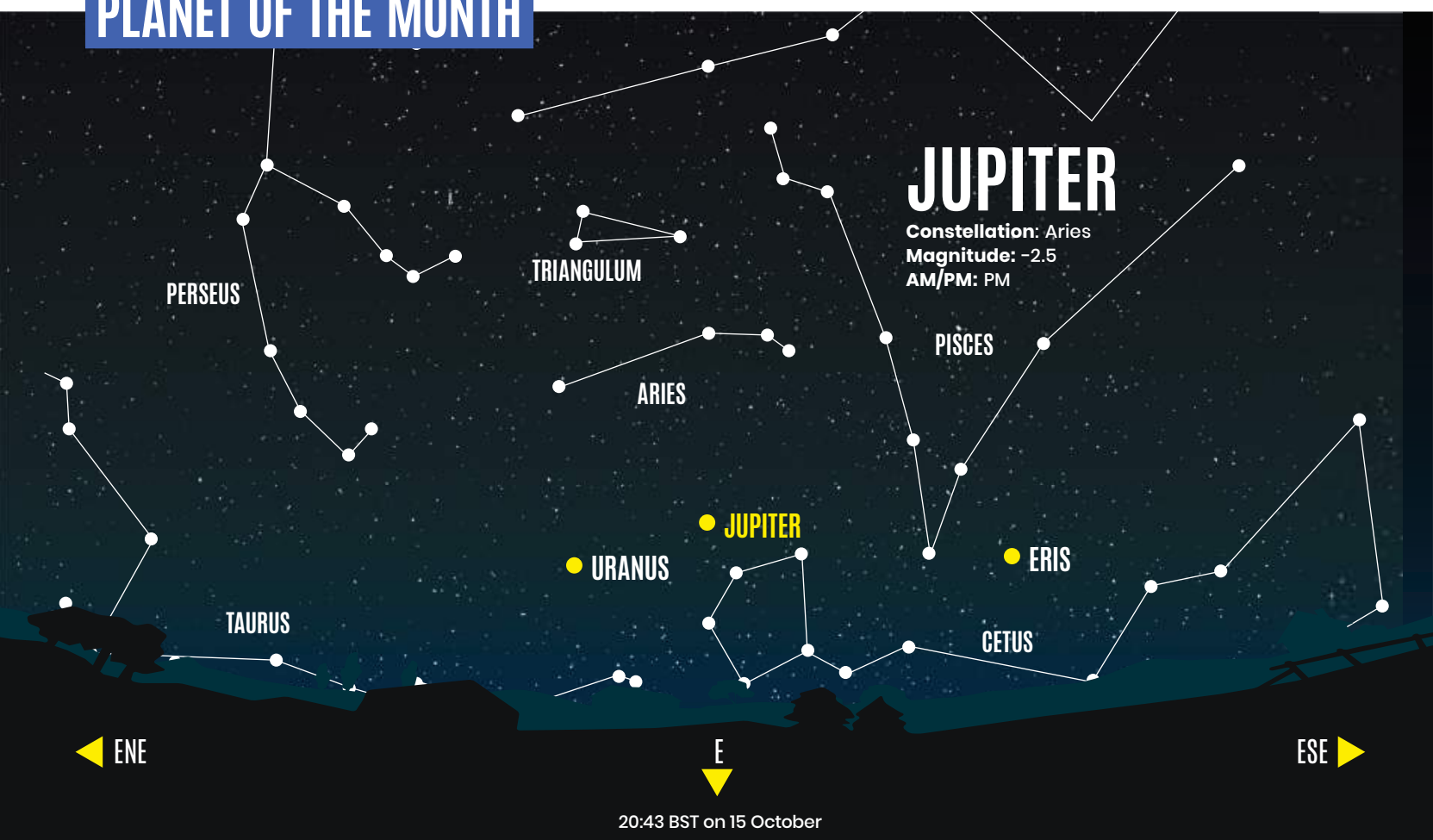
All rise and set times are given in BST/GMT

DATE	RA	DEC	CONSTELLATION	MAG	RISE	SET
5 OCT	12h 01m 45s	+01° 52' 34"	Virgo	-1.1	05:54	18:21
12 OCT	12h 46m 43s	-03° 19' 23"	Virgo	-1.3	06:38	18:12
19 OCT	13h 30m 49s	-08° 30' 40"	Virgo	-1.6	07:21	18:01
26 OCT	14h 14m 05s	-13° 17' 57"	Virgo	-1.2	08:02	17:51
2 NOV	14h 57m 09s	-17° 29' 51"	Libra	-0.8	07:43	16:42
5 OCT	09h 50m 55s	+10° 28' 13"	Leo	-4.5	02:59	16:55
12 OCT	10h 14m 42s	+09° 16' 50"	Leo	-4.5	03:01	16:45
19 OCT	10h 40m 13s	+07° 41' 13"	Leo	-4.5	03:08	16:34
26 OCT	11h 06m 59s	+05° 44' 09"	Leo	-4.4	03:17	16:23
2 NOV	11h 34m 40s	+03° 28' 37"	Leo	-4.3	02:29	15:12
5 OCT	12h 26m 47s	-09° 19' 24"	Virgo	+1.7	08:22	18:54
12 OCT	13h 50m 18s	-11° 04' 41"	Virgo	+1.6	08:22	18:35
19 OCT	14h 08m 26s	-12° 46' 48"	Virgo	+1.6	08:22	18:16
26 OCT	14h 26m 57s	-14° 24' 54"	Libra	+1.6	08:22	17:58
2 NOV	14h 45m 54s	-15° 58' 13"	Libra	+1.5	07:22	16:40
5 OCT	02h 46m 53s	+14° 37' 12"	Aries	-2.8	19:33	10:16
12 OCT	02h 44m 02s	+14° 23' 39"	Aries	-2.9	19:04	09:44
19 OCT	02h 40m 46s	+14° 08' 20"	Aries	-2.9	18:35	09:12
26 OCT	02h 37m 14s	+13° 51' 47"	Aries	-2.9	18:05	08:39
2 NOV	02h 33m 32s	+13° 34' 36"	Aries	-2.9	16:32	07:02
5 OCT	22h 14m 32s	-12° 48' 08"	Aquarius	+0.6	17:22	03:16
12 OCT	22h 13m 22s	-12° 54' 09"	Aquarius	+0.6	16:54	02:46
19 OCT	22h 12m 28s	-12° 58' 30"	Aquarius	+0.7	16:26	02:18
26 OCT	22h 11m 52s	-13° 01' 05"	Aquarius	+0.7	15:58	01:49
2 NOV	22h 11m 35s	-13° 01' 52"	Aquarius	+0.7	14:30	00:21

THIS MONTH'S PLANETS

The king of the Solar System shines brightly in the evening sky, offering a splendid view for astronomers

PLANET OF THE MONTH



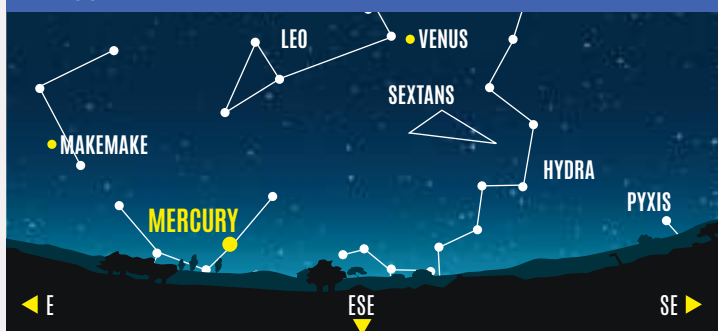
Jupiter is our planet of the month because it has some fascinating company in the night sky, and also because it will be ideally placed for everyone to observe, whether they're looking at it with the naked eye or zooming in on it with a telescope. Jupiter will spend the whole of our observing period in the rather star-starved constellation of Aries, an unremarkable spray of stars to the west of Taurus. At the start of October Jupiter will be rising at sunset and will then be visible all through the night until it sinks into the west as dawn approaches. With a magnitude of -2.8, Jupiter will be a very stunning naked-eye object, looking like a bright blue-white 'star' a short distance to the west of the famous naked-eye star cluster, the Pleiades.

Jupiter will remain in the same place all through the month, keeping the Pleiades company in the sky as October moves towards November. At the end of October Jupiter will be joined in the sky by a big, bright Moon, and the pair will make a very attractive sight, visible through binoculars and bright enough to take photos with just the camera on your phone. Look out for the blazing full Moon shining to the upper right of Jupiter as darkness falls on the evening of 29 October, and on the following evening too, when the Moon will have moved eastwards along its track and will be shining to the left of the giant planet.

All through the month ahead, Jupiter will be a fine target for binoculars and telescopes. Through a good binocular, Jupiter will appear as a very bright, intense

'star'. You'll need more magnification to see its disc, but even binoculars will be powerful enough to reveal some of Jupiter's huge family of moons. The four brightest, the Galilean moons, can be seen through binoculars as stars close to Jupiter, in a line on either side of it. The actual number you will see, and their arrangement, changes from night to night.

A small telescope will be powerful enough to show you Jupiter's slightly flattened disc, and the more magnification you can use, the more detail you'll see on that disc. Magnified 100x or more, Jupiter's pale lemon-grey disc is crossed by horizontal bands or stripes of tan and brown clouds. If you're looking at the right time you'll be able to catch a glimpse of the planet's famous Great Red Spot.

MERCURY 07:00 BST on 8 October

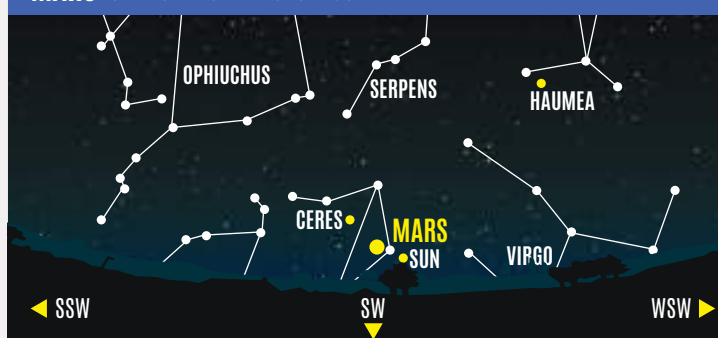
Constellation: Leo **Magnitude:** +0.4 **AM/PM:** AM

At the start of our observing period Mercury will be a morning star in Virgo, to the lower left of much brighter Venus and rising around an hour before the Sun. It would be a striking sight in a darker sky, but low in the predawn sky it will be challenging to see, especially if you have any trees, buildings or hills on your eastern skyline.

VENUS 07:00 BST on 8 October

Constellation: Leo **Magnitude:** -3.9 **AM/PM:** AM

At the start of October Venus will be rising some four hours before the Sun, giving you plenty of time to enjoy seeing it blazing in the predawn sky like a lantern. By 1 November Venus will be rising four-and-a-half hours before the Sun and will almost have moved across Leo's border with Virgo.

MARS 16:00 GMT on 5 November

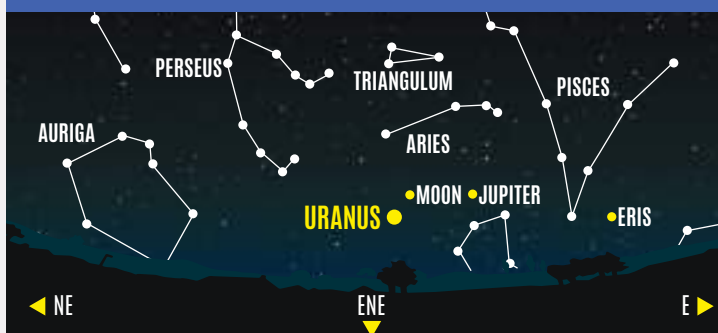
Constellation: Leo **Magnitude:** +1.8 **AM/PM:** PM

At the start of our observing period, Mars will be too close to the Sun to be visible. Setting just a few minutes after the Sun, Mars will be lost in its glare, and each evening will draw even closer to it making it even harder to see. By the start of November Mars will still be too close to the Sun to be observable.

SATURN 19:00 GMT on 2 November

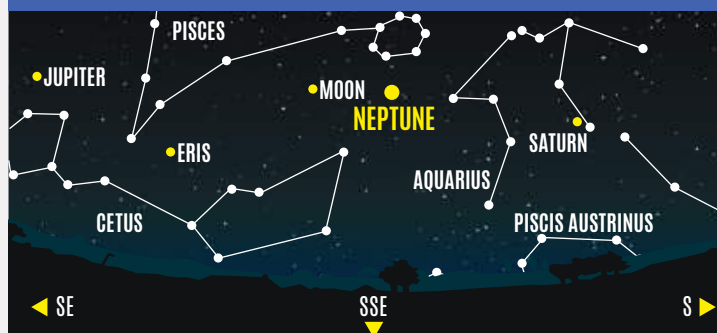
Constellation: Aquarius **Magnitude:** +0.5 **AM/PM:** PM

Saturn will be an evening object this month, looking like a yellow-white 'star' to the naked eye. At the start of October Saturn will already be well above the southeastern horizon as the sky darkens after sunset. By 2 November Saturn will be shining at magnitude +0.7 and will be setting before 01:00.

URANUS 18:00 GMT on 29 October

Constellation: Aries **Magnitude:** +5.8 **AM/PM:** PM

This coming month Uranus will very usefully lie halfway between brilliant Jupiter and the sparkling Pleiades star cluster, so to find it all you have to do is slowly sweep your binoculars away from Jupiter and towards the Pleiades. When you spot a slightly green-hued star, that's Uranus.

NEPTUNE 21:00 BST on 26 October

Constellation: Pisces **Magnitude:** +7.8 **AM/PM:** PM

At the start of October Neptune will already be in the sky as the Sun sets, a tiny 'star' to the east of brighter Saturn. By the start of November Neptune will be setting around 03:00, giving you less time to observe it with your telescope. Look for a waning gibbous Moon to Neptune's lower right on the evening of 25 October.

MOON TOUR

HARPALUS CRATER

Our destination this month is the star of one of the most famous sci-fi films ever made

This crater was the uncredited star of a film that was released 18 years before *2001: A Space Odyssey* and stunned audiences with its realistic depiction of space exploration. That film was *Destination Moon*. Of course, many lunar features and landmarks have been featured in science-fiction films and TV shows over the years. Some of the very first science-fiction films were silent movies that showed people visiting the Moon in glorified artillery shells fired from huge cannons to meet either bizarre-looking aliens or dancing girls.

In the aforementioned classic *2001*, astronauts excavated an enigmatic alien monolith from deep beneath the crater Clavius. In *Star Trek: First Contact*, the USS Enterprise's time-travelling first officer Riker waxes lyrical to warp drive inventor Zefram Cochrane about gazing up at the terraformed Moon in his century and seeing the lights of cities shining there, and Lake Armstrong too. The Moon has even been visited by *Spongebob*!

But in 1950 the film *Destination Moon* was the first to attempt to show the Moon, and the view from it, realistically by featuring the stunning artwork and models of artist Chesley Bonestell. Many consider Bonestell to be the original 'space artist'. Although his lunar landscapes were much more dramatic and jagged than the ones the Apollo astronauts would gaze out on and explore decades later, they were still far more realistic than anything painted or shown on screen before.

When *Destination Moon* came out, 19 years before Apollo 11 landed on the Moon for real, it took audiences on a thrilling mission to a real crater you can find for yourself this month: Harpalus. Sitting almost in the centre of Mare Frigoris, 'the Sea of Cold', a long, narrow stain just above the beautiful crescent-shaped Sinus Iridum in the far northerly reaches of the Moon,

TOP TIP!

Look for Harpalus when it is close to the 'terminator', the line between lunar night and day, when it will stand out much more clearly.

Harpalus is a physically small crater just 40 kilometres (25 miles) across and three kilometres (1.8 miles) deep. It's less than a third as wide as Copernicus and just one eighth the size of Clavius. Visually, it's an unremarkable feature, not helped by the fact that its close proximity to the lunar north pole means that our view of it from here on Earth is greatly foreshortened, so it usually looks like more of an oval than a circular feature. Sometimes the Moon's libration – the axial wobble which causes it to occasionally but regularly tilt features around its limb towards us and then away from us again, means we can occasionally see a little way around the edge of the Moon, sometimes causing Harpalus to be tipped towards us, allowing us a much better view. This month Harpalus will be well placed for observation.

Photos taken from directly above by orbiting probes show Harpalus is roughly

circular, with shallow, terraced walls, a trio of low mountains rising up from its hummocky floor and a system of rays spreading away from it. In this way it looks rather like a smaller version of the 'celebrity' crater Copernicus. If you look at Harpalus through a small telescope, you will be able to see right into it and will be able to make out details on its walls and floor, including a small crater there.

When can you see this crater at its best this month? On the evening of 5 October, the crater will be in full sunlight and very easy to see in a small telescope. It should even be visible – just – through a good pair of binoculars. The crater will remain fully illuminated until 9 October, when the terminator will begin to sweep over it, cutting off the sunlight. By the evening of 11 October, Harpalus will be out of our view once more before returning on 27 October.





NAKED EYE AND BINOCULAR TARGETS

As winter looms on the horizon, relax by enjoying these celestial treats

1 Pollux (Beta Geminorum)

Pollux is the second-brightest star in Gemini and the 17th brightest in the sky, shining at a magnitude of +1.14. It is also one of the few naked-eye stars we know has an extrasolar planet orbiting it, which is bigger than Jupiter and orbits Pollux once every 589 days.

2 Betelgeuse (Alpha Orionis)

Betelgeuse is an enormous red star, with a diameter over 650 times that of our Sun. With its distinctive orange-red colour and magnitude of +0.42, the supergiant star is immediately visible to the naked eye, rising in the east after sunset during the evenings.

3 Orion Nebula (Messier 42)

This is probably the most famous nebula in the entire sky. It's a vast, glowing cloud of gas and dust – a 'stellar nursery' where stars are being born. A 'fuzzy star' to the naked eye, binoculars show it as a small misty-grey smudge on a moonless night.

4 Sirius (Alpha Canis Majoris)

By far the brightest star in the sky at magnitude -1.46, Sirius is just 8.7 light years away, making it the fifth-closest star to us. To the naked eye, Sirius is a striking blue-white star that shimmers and twinkles dramatically as it shines above the horizon.

5 Messier 41

This star cluster is 2,350 million light years away. Although it's bright enough for the naked eye to see under skies untouched by light pollution, you'll need binoculars to spot this small but pretty star cluster. You can find it shining just beneath Sirius, and it will be quite low in the sky all night.

DEEP SKY CHALLENGE

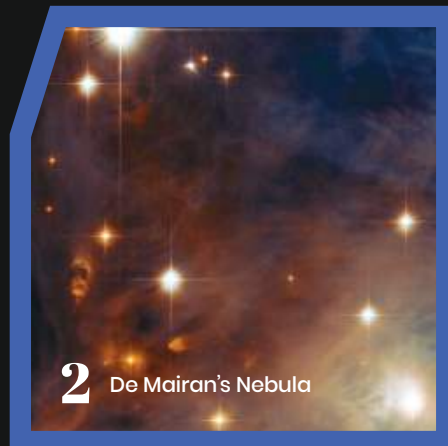
TACKLE THE TREASURES OF ORION

Turn your telescope to the Hunter and you'll be rewarded with a splendid selection of deep-sky targets. Some are easy, but some are a little harder to spot

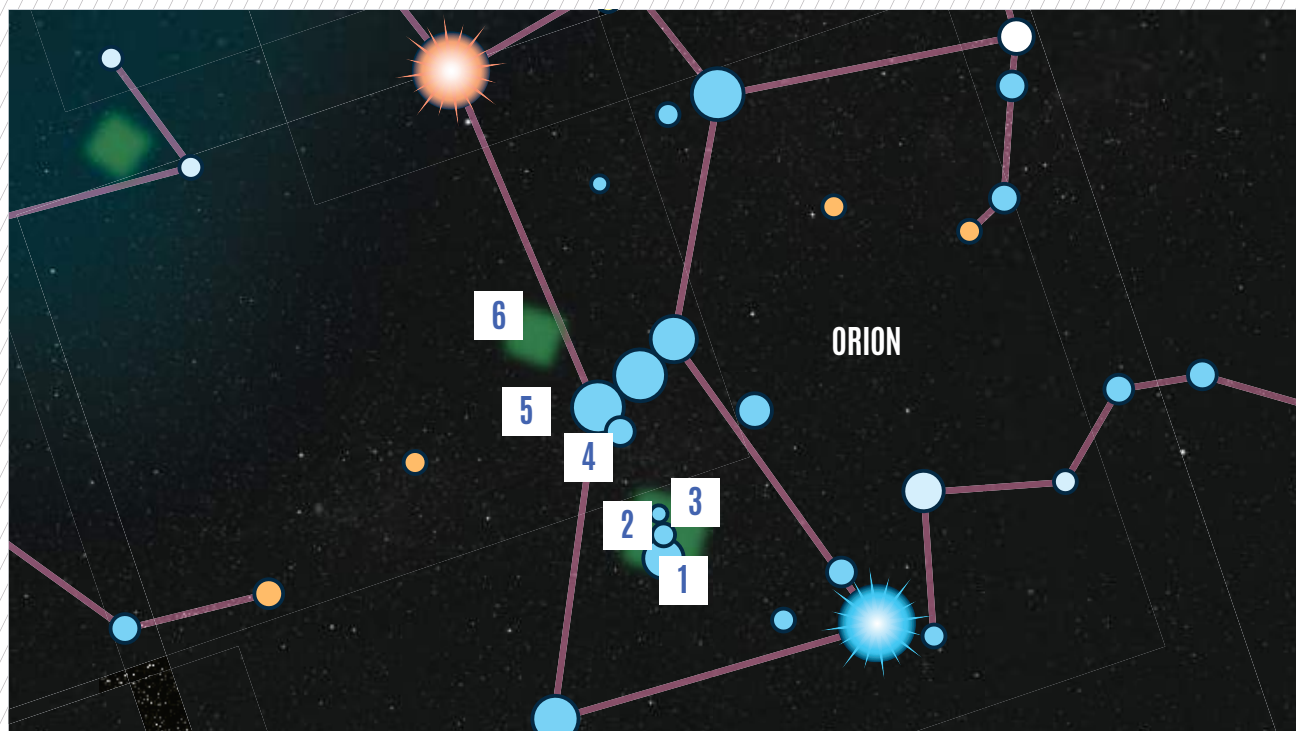
The constellation of Orion (the Hunter) is littered with deep-sky objects to explore. There are star clusters and nebulae, and that's not including one of the most famous star-forming regions, the Orion Nebula (Messier 42). Orion is a treasure trove for those interested in seeking out challenges for eye and telescope alike. The stunning

Orion Nebula is easy to spot as one of the brightest nebulae, and is even discernible to the naked eye under the most mediocre of observing conditions.

Nearby, another well-known nebula rests that is a lot trickier to spot, and really needs a filter to help make it out: Barnard 33, dubbed the Horsehead Nebula for its equine silhouette, which is created by pillars of gas and dust.



2 De Mairan's Nebula



© Will Tirion; NGC/ESO/Igor Chokalin; ESA/Hubble & NASA

1 The Orion Nebula (Messier 42)

Using your telescope or a decent binocular, look for the four bright stars at its heart: the Trapezium Cluster. Small telescopes at higher magnifications will reveal four of the cluster's brightest stars.

2 De Mairan's Nebula (Messier 43)

This nebula sits on top of the much larger Messier 42 and can be resolved using a medium-powered eyepiece. The object appears separated by a dark dust lane in the foreground. The nebula is bursting with a wealth of star formation.

3 Running Man Nebula (NGC 1977)

Also known as NGC 1977, this beautiful object is a combination of a reflection nebula and HII region. You will need a medium-sized telescope and filters to truly play up the layers of gas and dust.

4 Horsehead Nebula (Barnard 33)

A difficult object to see visually due to its low contrast, the Horsehead Nebula requires a medium or large-aperture telescope and a H-beta filter in order to pick out its structure. Imaging can bring out its pink glow, caused by hydrogen gas.

5 Flame Nebula (NGC 2024)

NGC 2024 is also known as the Flame Nebula. Alnitak, the brightest star in Orion's Belt, shines ultraviolet light into the Flame Nebula to give it its stunning glow. Filters will help you play up the object's true splendour.

6 Messier 78

There's a star embedded in this nebulousity, which reflects its light and allows observers to make out the tenuous gas, even with a small telescope. Two stars are responsible for making the cloud of dust – HD 38563A and HD 38563B.



3 Running Man Nebula (NGC 1977)

NORTHERN HEMISPHERE

The clocks go back at the end of this month, giving more time to view a splendour of night-sky objects

Andromeda, Cassiopeia and Sculptor are just some of the constellations offering a selection of targets for telescope and binocular-wielding astronomers this month. With the Sun dipping below the horizon earlier in the evening, those wanting to catch new or favourite targets don't have to wait long for dark skies to boast these treasures. Head over to Andromeda and you'll be rewarded with not just its spiral galaxy, Messier 31, but also its dwarf elliptical galaxies Messier 32 and Messier 110. While the parent galaxy is easy to spot, you'll need at least a medium-sized telescope to spot Andromeda's satellites. Star clusters are a joy to behold in Cassiopeia, which can be spotted with ease by its 'W' shape.

Using the sky chart

This chart is for use at 22:00 mid-month and is set for 52 degrees latitude.

- 1 Hold the chart above your head with the bottom of the page in front of you.
- 2 Face south and notice that north on the chart is behind you.
- 3 The constellations on the chart should now match what you see in the sky.



Magnitudes

- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to +0.5
- +0.5 to +1.0
- +1.0 to +1.5
- +1.5 to +2.0
- +2.0 to +2.5
- +2.5 to +3.0
- +3.0 to +3.5
- +3.5 to +4.0
- +4.0 to +4.5
- Fainter
- Variable star

Spectral types

- O-B ● G
- A ● K
- F ● M

Deep-sky objects

- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies



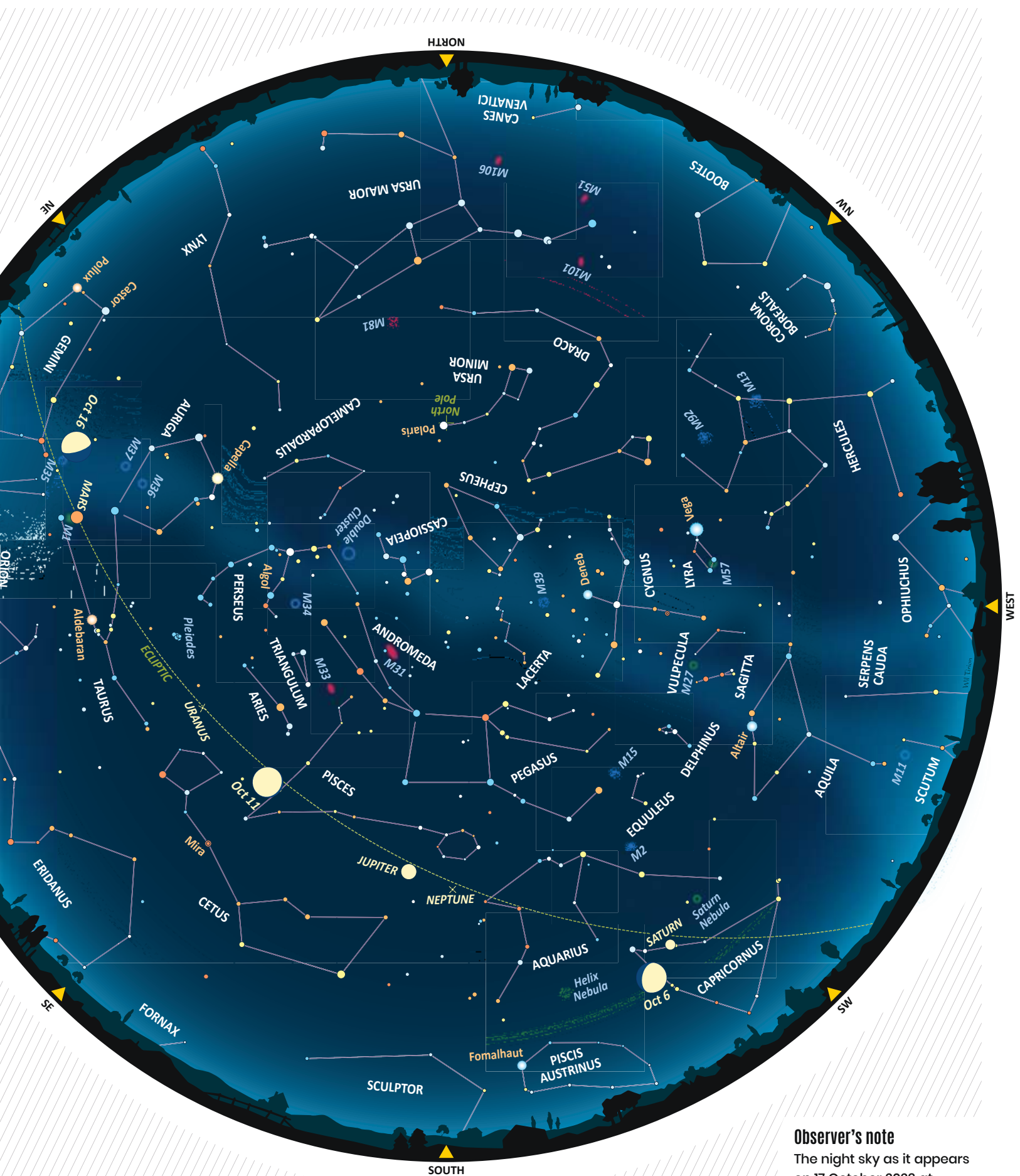
Andromeda Galaxy (Messier 31)



The Heart and Soul Nebula



Sculptor Galaxy (NGC 253)



Observer's note

The night sky as it appears
on 17 October 2023 at
approximately 22:00 (BST)

REVIEW

SKY GUIDE

This visually appealing and informative stargazing app now comes in a free version with impressive in-app upgrades

Reviewed by Jamie Carter

DETAILS

From: Fifth Star Labs

Cost: Free with in-app purchases

Operating system: iOS

Size: 324.1 megabytes

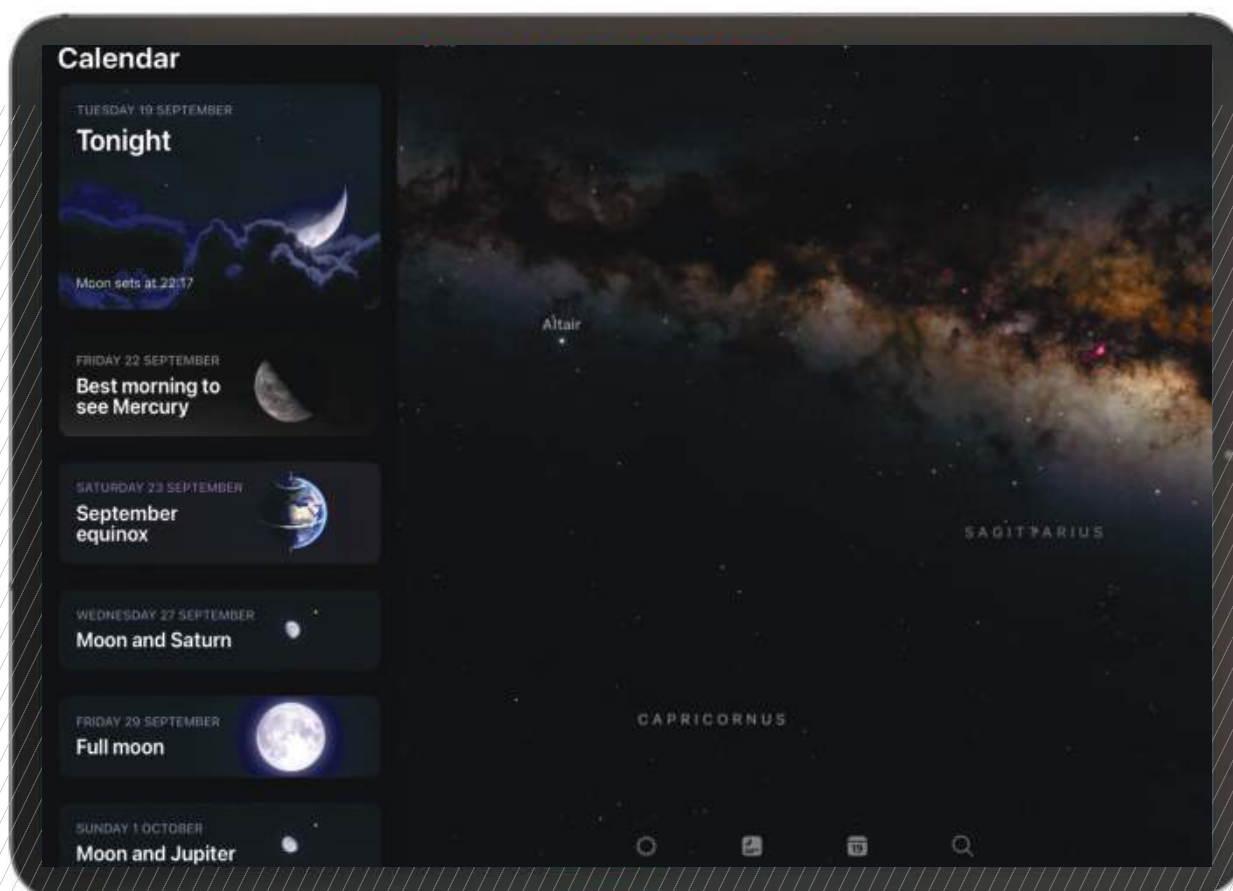
✓ The Sky Guide app is available for iPad devices if you prefer to use a larger screen

Planetarium apps like Sky Guide have been around for many years, and yet their use of augmented reality (AR) to show you the stars still has the power to hugely impress. Now ten years old, this latest version of Sky Guide, called Version X, has decided it's time to go free... almost. Despite being filled with new visualisations and lots of up-to-the-minute content, Sky Guide now comes as a free download, though serious users will want to download one of its two in-app upgrades: Sky Guide Plus or Sky Guide Pro. Either way, what you get is easily one of the best stargazing apps around.

Originally launched in 2013, the latest version of Sky Guide is the creation of Fifth

Star Labs. Sky Guide Version X launched in 2021 and comes in a free version. However, there are two add-on subscriptions available: Sky Guide Plus for £2.79 (\$2.99) per month or £17.99 (\$19.99) per year, and Sky Guide Pro at £4.49 (\$4.99) per month or £34.99 (\$39.99) per year. Sky Guide Plus dramatically increases the star and object catalogues, offering 100 times more stars, 10,000 times more satellites and 100x zoom.

It also adds information on how light-polluted observing sites are, as well as more advanced forecasts for meteor showers. Sky Guide Pro does all of that and more, adding a massive catalogue of 1.7 billion stars, including double and variable stars, over 1 million deep-sky objects, exoplanets





and 1,000x zoom. The Pro version also offers field-of-view visualisation tools and cinematic tours. Crucially, there's no need to upgrade blindly since both Sky Guide Plus and Sky Guide Pro come with a one-week trial period, allowing you to cancel if you find that you don't use the extra features. If you've ever purchased Sky Guide before, you'll retain the same features you paid for.

Sky Guide looks incredible. Hold it up to the sky in front of you and it displays the Milky Way and dynamic displays of the aurora borealis and aurora australis, though this can be toggled off. Bright stars and planets are labelled, with fainter objects

revealed the more you pinch to zoom in on the night sky. There's an AR mode to overlay this data via a smartphone's camera, which is useful for identifying obstacles. With that comes the pièce de résistance: an AR mode that uses the lidar chip in Apple devices to substitute a ceiling for the night sky. It's clever stuff, as it has the ability to sub in realistic magnitudes while taking into account horizon haze, and has the all-important Night Vision mode to display everything in less damaging red light.

The planetarium page is uncluttered, with icons down the bottom for Settings, Featured, Calendar and Search. Going

BEST FOR...

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-  AMATEUR ASTRONOMERS
-  INTERNATIONAL SPACE STATION OBSERVATIONS
-  SOLAR SYSTEM OBSERVATIONS
-  DEEP SKY OBSERVATIONS

< The app excels at letting you know what you can see on a particular night

✓ Sky Guide also works with the Apple Watch, but in a more limited capacity

into the Settings menu allows the toggling on and off of constellation lines, mythological constellation art, object labels and satellites. Featured is a blog-style scrolling section of news articles, a constellation of the month feature and sky sights of the month round-ups. Next comes Calendar, which begins with a bite-size forecast of when you'll have a clear sky and then presents a date-driven list of celestial events coming up, such as Moon phases, conjunctions and meteor showers. Click on any of them and you get an image, a description, some background information and, best of all, the chance to inspect it in Sky Guide's planetarium. It's useful to see exactly what will be visible for many nights or weeks ahead, but it would be even better if they could be saved to an observing list



“The Pro version also offers field-of-view visualisation tools and cinematic tours”

STARGAZER

and allow a notification to be configured as a reminder. Meanwhile, Search contains a link to tonight's best, which includes planets, bright stars and constellations. Everything is presented in a colourful, well-designed manner that never looks crowded or off-putting.

Sky Guide goes all-in on Apple devices and ignores Android. For now that means it's available on iPhone and iPad, but also on Apple Watch, where it shows a variety of simple screens: Earth with the position of the International Space Station (ISS) in orbit, the Sun with the latest space weather reports, a simple clock face with a dynamic Moon phase icon and a page giving a countdown to the next visible ISS pass. Sky Guide also has an eye on the future. In June 2023 it featured in Apple's Worldwide Development Conference 2023 Keynote as a fully immersive version specifically for the forthcoming Apple Vision Pro spatial computer headset.

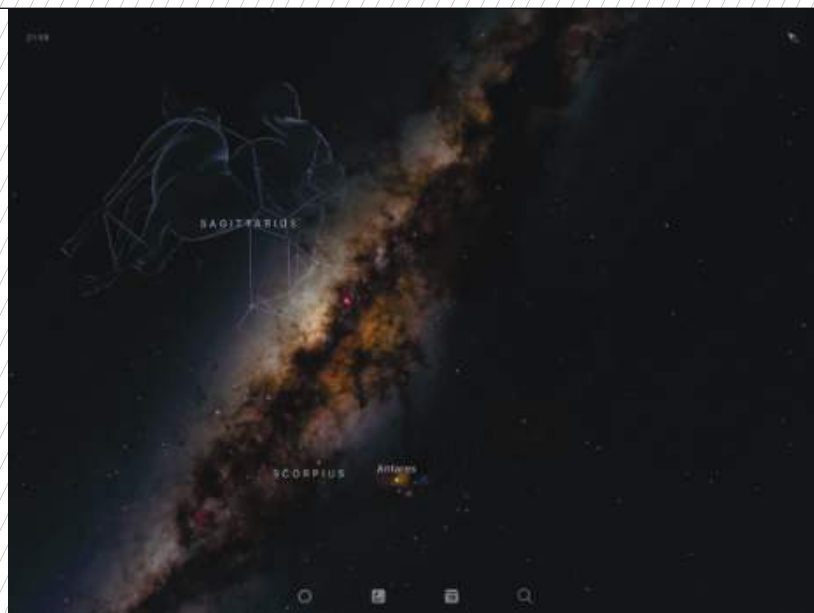
Sky Guide looks simple, uncluttered and is easy to use, but it's packed with simple customisation features. One of the most useful, which is available in the basic free version, is notifications. Accessed via the Settings menu, it's possible to set reminders for astronomical events and satellite passes over your location by the ISS. Helpfully, it's also possible to tweak how much notice it gives you before each event is visible, set a 'do not disturb' timer and opt in or out of notifications about news articles published on Sky Guide.

By default, Sky Guide features 24 constellations, 100 deep-sky objects and ISS tracking, which is likely enough for casual stargazers, but the Plus and Pro in-app purchases are worth considering for serious amateur astronomers. As well as a larger database, you get meteor shower forecasts tailored to your location and a dark sky finder for your local area. Meanwhile, Pro expands the database further, adds exoplanets and cinematic tours and brings to life greyed-out options in the Settings menu for setting fields of view for equipment, an imaging calculator for working out exposure times and the ability to input coordinates.

Since Sky Guide identifies objects in the night sky, it's useful for helping astrophotographers orient a camera, though the Plus and Pro in-app purchases are advisable if you're photographing deep-sky objects such as nebulae. Just as important to most will be the notifications for upcoming events – just remember to

set the alert to an hour or more before the event if you need lots of time to set up or to get to a specific location.

If you're after an app that gives you an easy-to-use, comprehensive and beautiful-looking planetarium, but which also comes with the latest news articles about astronomy, Sky Guide is hard to beat. The customisation options are great, as well as the notifications about upcoming celestial events. However, it's a shame that there are no upgrades for Wi-Fi telescope control and that future events can't be saved to observing lists. Overall, Sky Guide is a really impressive app that will delight most casual stargazers and amateur astronomers alike.



▲ Constellation art can be switched off if you prefer

◀ Astronomy news is easily accessible and kept up to date

▶ You'll never miss an exciting event in the sky again



FOR

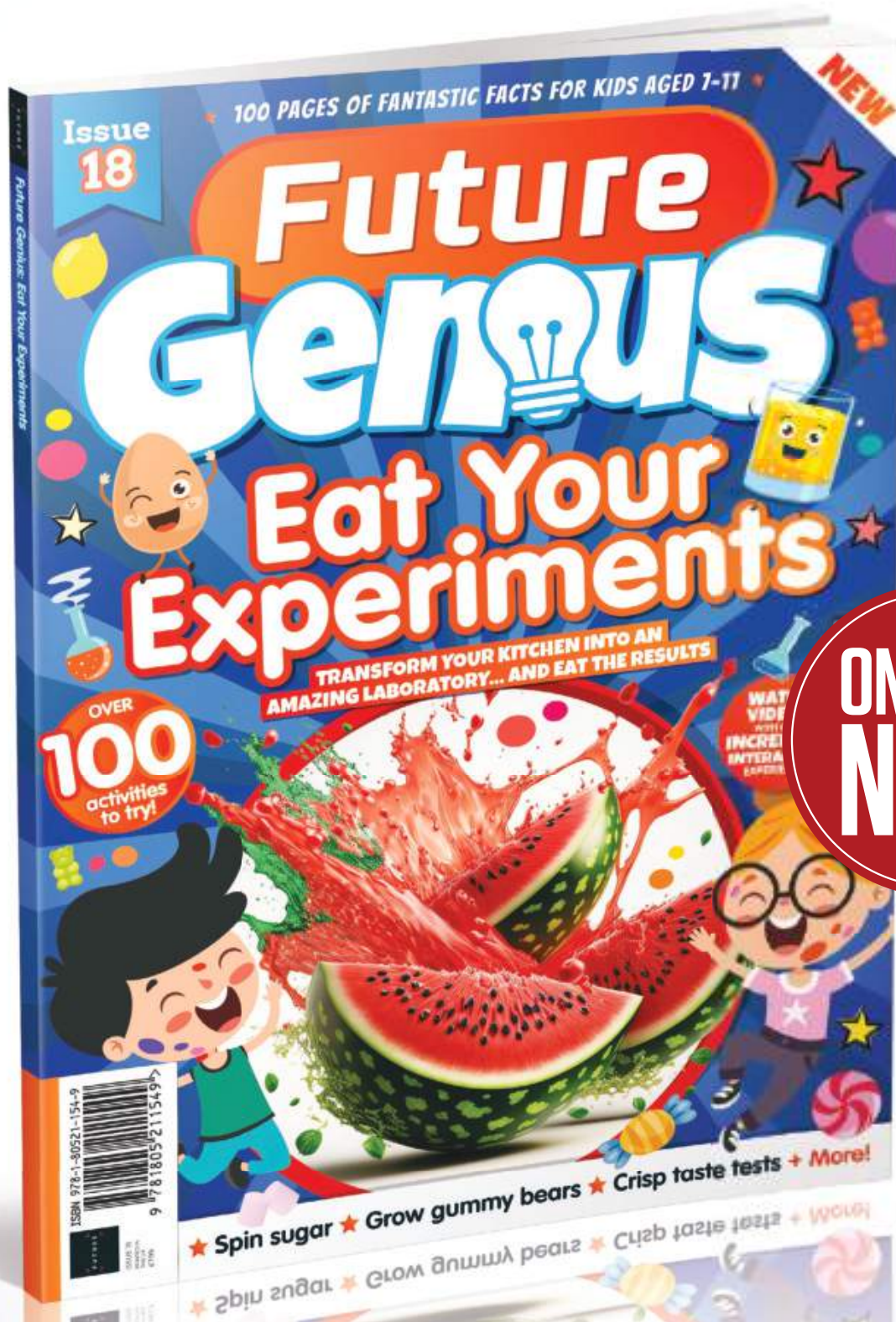
- ⊕ Attractive user interface
- ⊕ Built-in weather forecast
- ⊕ Clever AR modes
- ⊕ Regular astronomy news articles

AGAINST

- ⊖ No Android version
- ⊖ No telescope control
- ⊖ In-app purchases recommended
- ⊖ Observing lists can't be saved

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IN THE SHOPS: DSLR CAMERAS

Here's our round-up of the best digital cameras on the market right now



Nikon D850

Cost: £2,699 / \$2,999.95

From: Nikon

1 The D850 offers 45.7-megapixel photos at up to nine frames per second, albeit only when using a dedicated battery grip. It's not as high as some of the other cameras here, but you must bear in mind that this is nine frames per second of full-resolution still images at 45.7 megapixels – these images are enormous. If you're someone who likes to switch between capturing stills and shooting video, the D850 is worth a serious look as it also shoots in 4K ultra-high definition (UHD). What's more, this camera is extensively weather sealed, and even the battery grip is protected from dust and water. The Nikon D850 is a camera you can take anywhere, getting maximum results without fretting about the elements.



Canon EOS 90D

Cost: £1,299.99 / \$1,199

From: Canon

2 Crop-sensor DSLRs benefit from the perceived extra zoom afforded by the 1.5 to 1.6x effective crop. That's exactly where Canon excels with this powerhouse of a camera. The longer effective focal length and fast ten frames per second burst speed are complemented by a huge 32.5-megapixel CMOS image sensor. It would have been nice to see 4K digital cinema initiatives (DCI) on this camera, but 4K UHD more than keeps up with the rest of its class and is suitable for most shooters. A 220,000 RGB and IR metering sensor powers the iTR focus tracking, allowing you to keep fast-moving subjects sharp even when you're moving the camera.



Canon 5D Mark IV

Cost: £2,789.99 / \$2,699

From: Canon

3 Despite being released over seven years ago, the Canon EOS 5D Mark IV is still the chosen tool of many professionals. It is a must for its quality alone, as it captures 30.4-megapixel stills and shoots in 4K DCI video for cinema-like movie quality. A large, detailed rear screen complements the bright optical viewfinder, and peripherals can be attached with USB 3.0, HDMI out and headphone outputs. It also features a microphone input, a flash connection port and WiFi and NFC technology to facilitate wireless shooting and easy image sharing.



4



6



5

“We were pleasantly surprised when we used it for some very basic astrophotography”

Nikon D7500

Cost: £1,049 / \$999.95

From: Nikon

4 Engineered for photographers who want to take their photography to the next level, the D7500 is Nikon's flagship DX crop-sensor camera body. It has a large 3.2-inch rear-tilting LCD, making it helpful when shooting at awkward angles. It's also a touchscreen that makes composing and shooting a breeze with as few clicks as possible. It's suitable for some sports and wildlife photography thanks to the eight frames per second maximum burst speed, and the 20.9-megapixel CMOS image sensor is more than enough to shoot 4K UHD video. This camera is protected from the elements as its all-around weather sealing prevents water and dust ingress.

Canon EOS Rebel SL3

Cost: £689.99 / \$649.99

From: Canon

5 While there are cheaper entry-level crop-sensor cameras, the tiny Canon EOS Rebel SL3 is the best of the bunch with a 24.1-megapixel CMOS sensor and a DIGIC 8 image processor that produces vivid photos. There are only nine autofocus points across the viewfinder, but engaging the live view option on the vari-angle touchscreen improves this to 143 via camera automatic selection. This Canon also has a -4EV autofocus working range and a maximum expanded ISO sensitivity of 51,200. It's quite a handy camera in low-light conditions, especially if you pair it with a lens with built-in image stabilisation. We were pleasantly surprised when we used it for some very basic astrophotography.

Nikon D780

Cost: £2,099 / \$2,299.95

From: Nikon

6 Superseding the magnificent D750, the Nikon D780 builds on its predecessor's specifications and features a more detailed rear screen with a huge maximum burst speed of 12 frames per second. This makes it an ideal DSLR for wildlife, sports and action photography. It shoots 4K UHD video with 10-bit N-log recording and 12 stops of dynamic range. A low-light master, this model can expand the ISO range to a ridiculous 204,800 and the noise-reduction algorithms are impeccable at keeping the images clean. In addition, its low-light-specific autofocus ability can drop the camera's autofocus as low as -7EV when live view is activated – especially useful for astrophotography.

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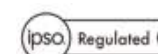
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MICHAEL S. HOPKINS

NASA astronaut and SpaceX Crew Dragon commander

Hopkins served as the commander on Crew-1, which launched on 15 November 2020. The mission represented the first commercial crewed spacecraft to travel to the International Space Station. He was a flight engineer on the ISS for Expedition 64, his second long-duration space mission. On his first, Expedition 37/38, Hopkins spent 166 days in space. During that time, he logged almost 13 hours of spacewalks. Hopkins became the first US military transfer in space, as he voluntarily transferred from the US Air Force to the US Space Force.

Hopkins was born in Lebanon, Missouri, on 28 December 1968 and grew up on a farm outside Richland, Missouri. After graduating from school, he attended the University of Illinois, where he completed a bachelor of science in aerospace engineering in 1991. He attended Stanford University to study for a master of science degree in aerospace engineering in 1992.

Hopkins was commissioned as a second lieutenant in the US Air Force, and from 1993 was based at Kirtland Air Force Base in Albuquerque, New Mexico, where he worked on space systems technologies. Three years later, he enrolled in a US Air Force Test Pilot School flight test engineering course at Edwards Air Force Base in California. He graduated in 1997, after which he tested C-17 and C-130 aircraft at the 418th Flight Test Squadron.

In 1999, Hopkins was part of an exchange program with the Canadian Flight Test Centre in Cold Lake, Alberta. In 2002, the George and Carol Olmsted Foundation selected Hopkins as an Olmsted scholar. The program offers military members a two-year immersion in another country and culture; in 2003, following six months of language training, Hopkins moved to Parma, Italy, where he studied political science at the Università degli Studi di Parma.

Upon his return to the US in 2005, he served as project engineer and program manager in the US Air Force Rapid Capabilities Office at the Pentagon. In 2008 Hopkins became special assistant to the vice-chairman of the Joint Chiefs of Staff. In 2009, Hopkins was selected as part of NASA's 20th astronaut class. He graduated from astronaut candidate training in 2011. Hopkins' first assignment in space was in 2013. Along with Russian cosmonauts Oleg Kotov and Sergey Ryazanskiy, Hopkins travelled to the ISS aboard the Soyuz TMA-10M spacecraft as a member of Expedition 37/38.

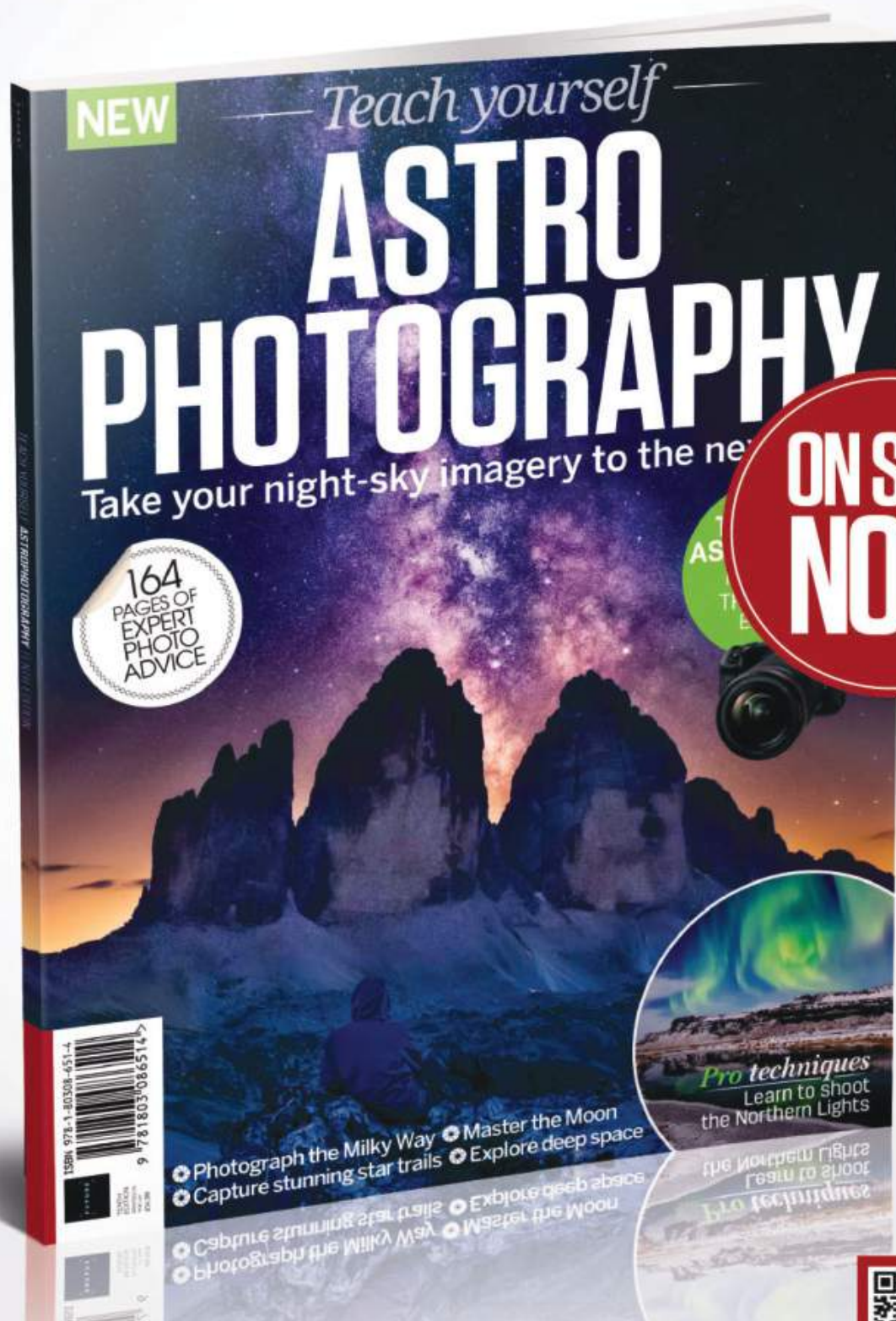
Hopkins was commander of the Crew-1 SpaceX Crew Dragon, humanity's first private crewed spacecraft to travel to the ISS. The astronauts named the spacecraft 'Resilience' in recognition of the challenges that people faced and overcame during the COVID-19 pandemic of 2020.

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